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RESOURCES FOR TOMORROW

CANADA

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The Honourable Walter Dinsdale, P.C.,M.P.

Minister of Northern Affairs and National Resources

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Conference Background Papers

Supplementary Volume

February 1962

Two volumes containing eighty background papers were published July 1961 *in advance* of the discussions on renewable resources at the "Resources For Tomorrow" Conference held in Montreal, October 23-28, 1961.

This supplementary volume contains seven additional background papers which failed to be included in the first two volumes.

Another conference publication, on the proceedings of the Conference, will be available separately.

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OTTAWA,
February 1, 1962.

TO THE HONOURABLE WALTER DINSDALE,

CHAIRMAN,

STEERING COMMITTEE,

"RESOURCES FOR TOMORROW" CONFERENCE.

SIR,

It is my pleasure to submit to your Committee the remaining background papers prepared for the "Resources For Tomorrow" Conference held in Montreal, October 23-28, 1961.

These papers were available to Conference participants in preliminary form but were not received by the Secretariat sufficiently early to be included in the two volumes provided to you under date of July 14, 1961.

Respectfully submitted,

B H Kristjanson

B. H. Kristjanson,

Secretary,

"Resources For Tomorrow" Conference.

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IMPLICATIONS OF TECHNOLOGICAL CHANGE FOR AGRICULTURAL PRODUCTIVITY

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The "Implications of Technical Change in Agriculture" was the theme of the Ninth International Conference of Agricultural Economists held in Finland in 1955. At that conference various interpretations were given to the term "technical change". K.U. Pihala wrote as follows:

> "The words technical change tend to give an impression of something connected with machines. In their present context, however, the words are used in a broader sense to include all kinds of innovations produced by the mental ability of mankind and aimed at contributing to increased efficiency of production. Thus changes effected by breeding and improvements in cultivation and in the feeding of farm animals are included, as well as the invention of new machines and implements."

The following slight modification to the above interpretation is proposed and will be used in discussing "Implications of Technological Change for Agricultural Productivity".

> Technological change includes all kinds of innovations produced by the mental ability of mankind aimed at contributing to increased productivity.

Emphasis will be placed on gross production rather than on efficiency of production. It is inevitable that efficiency of production, as measured by output per man hour, will increase as rapidly as newer and better equipment and machines replace manpower. But as long as populations continue to increase, gross production is the important criterion for survival; efficiency

of production being considered important only as it affects gross production.

It is impossible to divorce from any logical discussion of gross agricultural production the available land resources and, more important, how the land resources may be affected by the diversified demands of an increasing population. First, therefore, a brief look at populations.

Responsible people in every part of the world are becoming increasingly concerned about the population explosion that is now taking place and that is likely to continue at an increasing pace for at least the next half century. Much has been written and varying opinions expressed about the race that lies ahead between population and food supply. The problem is clearly depicted in the opening paragraphs of a recent article entitled "Will there be standing room only?"

> "As a species, man is a phenomenal success. He has to his credit many triumphs. He has won dominion over all other animals; conquered many of the diseases that plague him; found ingenious ways to wrest sustenance from the earth's crust. And he has multiplied--but therein lie some problems.
>
> In less than 50 years, unless there is a catastrophe or a change in population trends, the world's population will have grown to some 6 billion.
>
> In 1957 and 1958 the earth's population grew by 90 million--as much as the entire population of Japan and twice that of France. In the next two years a further increase of 100 million is expected. By 1962 the world will have 3 billion people; 4 billion by 1977; 5 billion by 1990; and 6 billion before the year 2000.
>
> Never in the history of mankind have human beings multiplied so rapidly as in this century. It took 200,000 years for the world's population to reach 2.5 billion; now it will take only 30 years to add another 2 billion.

At the present rate of increase, in 600 years each human being will have only about one square yard to live on. It goes without saying that this can never take place; something will happen to prevent it."

More recently, in discussing population problems and man's future, C.F. Bentley presented the following interesting table to indicate how quickly continents can be repopulated at present rates of increase.

Period	Expected World Population Increase	Equivalent to or Exceeds:
1 year, 1960	45,000,000	2.5 times Canadian population
1960 - 1965	over 235,000,000	Population of Can., U.S.A., Mexico
1960 - 1970	over 500,000,000	Population of India, plus Pakistan
1960 - 1985	over 1,500,000,000	World population in 1900

If Canada, with her wide open spaces, were to take the 1960 world increase of 45 million people and provide them with the same standard of living the Canadian people now enjoy--with space to build homes, with parks in which to relax, with roads by which to commute readily from place to place--at least twice as much land would have to be taken out of production as is already occupied by our many cities, towns, parks and highways. Our present large grain surpluses would disappear in one year for domestic use and we would have to start an all out drive for self-sufficiency.

It is safe to suggest that a movement in the direction just outlined will be apparent in most regions in Canada by the year 1980, as it is indeed apparent in the more heavily populated areas today. The displacement in the Niagara Peninsula of vineyards and apple, peach and cherry orchards by industrial sites, highways, airfields and suburban subdivisions is already the cause of much concern. With continued application of technology on and off the farm compounded by a rapidly rising population we can expect much more of our best agricultural land to be lost to food and fibre

production in the decades ahead. Therefore a brief consideration of our future population trends, as they affect arable land area, seems pertinent to this discussion.

The Gordon Commission[1] forecast for the year 1960 a population of 17.5 million, for 1965, 19.5 million and by 1970, 21.5 million. Bloom in 1956 wrote:

> "The best estimates indicate a population of 17.5 million by 1960, 22 million by 1970 and close to 25 million by 1975; or an increase of between 9 and 10 million over the next 20 years...."

Within five years after the estimates were made the Canadian population exceeded the estimates by half a million. Therefore it appears reasonable to estimate that by 1980 Canada's population should be about 28 million or 10 million more than at present. This means that several million additional acres of productive soil will be taken out of production for non-agricultural purposes. This loss, already quite pronounced in Eastern Canada, will continue, particularly in the heavily industrialized regions where the greatest proportional increase in population is expected. When considering the loss of improved land acreage to agricultural production in Ontario the Gordon Commission[2] notes as follows:

> "Since the net reduction between 1941 and 1951 was almost 700,000 acres and since reduction has proceeded at an accelerated rate since 1951, the next 25 years will likely see a further reduction of 700,000 acres."

Even when considering the vast expanses of Western Canada the land resources are not inexhaustible. Bentley estimates that the communications systems alone occupy about two per cent of the land areas in most settled regions.

In terms of the impact on agricultural production it is important to note that in most instances the land that is lost to agriculture is the most productive land in the country. This is so because of the pattern of original settlement when agriculture was the only significant industry. It was natural that cities would be founded and roads would be built in the best and most thriving agricultural communities. Obviously then the loss of these

areas to agriculture is disproportionately large in terms of acres. We would do well to remind ourselves that this rapid loss of productive soil is not unique to Canada. With much greater numerical increases in populations in most other countries the non-agricultural demands on productive land are much greater than in this country. What is happening in other countries may well have an increasing significance to Canadian agriculture. Nations are no longer independent isolated islands unto themselves; each year, it seems, more of the facts of life imperative to survival in a world shrinking in dimensions of time and space are being forced upon us. One of these 'facts of life' may well be that we may not always be able to afford the luxury of looking upon our agricultural resources as being the rightful heritage of Canadians only. General MacArthur, while commanding U.S. forces in the Pacific dramatized this concept with his famous statement: "If food will not cross borders armies will."

Thus the universal dilemma is that ever more people are depending on a decreasing number of productive acres for their survival. But is not land only one of three basic ingredients of production--land, labor and capital? If more labor and capital are introduced into the food production formula can the proportion of land not safely be decreased? It is true that there is a degree of permissive substitution among these production factors but not to the extent that is popularly maintained. It will be shown later that the greatest interchangeability lies between labor and capital, but that land is a much more constant factor in agricultural production. The impact of technological change has represented primarily (although not wholly) a decrease in labor and an increase in capital inputs. This interchange of two of the three basic resources has increased the productive capacity per man and has been termed "efficiency of production", but this "efficiency" has not had much of an impact on total production because the land base has remained fairly constant.

This initial premise basic to a discussion of technology's impact on future agricultural production has been well stated by Bentley as follows:

> "Although the technology of food production by soilless procedures has made remarkable progress in recent years, land-based agriculture will probably continue indefinitely

> to be the principal source of food, and of many materials required by industry. At the least this will be true for many decades.
> The future of our nation is therefore related to the productivity of our agricultural lands."

Having considered in brief and general terms the steady erosion of fertile land by the forces of encroaching population, industry and service facilities, a similar brief and general look should be taken at the likelihood of virgin acres being claimed for agricultural production. This topic is thoroughly dealt with in a paper prepared by Dr. A. Leahey and therefore will not be considered in detail in this discussion.

Trends in the use of improved land[3] are presented below as recorded in the Gordon Commission report[4].

Millions of Acres

	Eastern Canada	Western Canada
1901	24.1	6.1
1911	25.2	23.5
1921	25.4	45.4
1931	25.2	60.5
1941	25.2	66.4
1951	23.9	72.9

After considering carefully the trends in land use in both Eastern and Western Canada the Commission concludes that it is unlikely that Canadian Agriculture will expand much into new farming areas. Although there may be pockets of potential farm land in Eastern Canada the Commission sees little likelihood of any of this being used for agricultural production. Indeed, the trend in Eastern Canada, as the data indicate, is more toward withdrawal from agricultural land than toward occupation of new territory. A net loss of about four million acres is predicted by 1980. In Western Canada about 7.5 million acres are seen as new land suitable for agricultural occupation over the next 25 years, but with the exception of some two million acres the extreme cost involved

in clearing and drainage renders development unlikely. Bentley, projecting his sights beyond the twenty-five year limit, estimates an additional 15 to 25 million acres of potentially arable land in Western Canada. Much of this, he concedes, is of low quality and superior soil management will be necessary for successful agriculture. In addition, most of these regions are in remote northerly areas isolated from transportation routes and markets. A combination of economic reality and government policy renders the exploitation of most of these areas highly unlikely. Dion essentially agrees with this appraisal. When writing about land use in Canada in 1956 he expressed his views as follows:

> ".....In the foregoing no attention has been given to the possibility of increasing agricultural acreage in Canada in the next 20 years. The best estimates of the Canada Department of Agriculture have indicated that the good land capable of easy development in Canada has largely been occupied..... No major invasion of the 50 million acres of land still capable of development is considered likely until necessary to meet food deficits."

Thus there seems to be general agreement that the occupation and improvement of virgin soils for agricultural use will be of fairly small proportion in the decades immediately before us. In Eastern Canada a decided trend in the direction toward a net loss in cultivated acreage is already established. In Western Canada, with a much greater virgin land potential and less of a population pressure, there may be a slight upward trend in acreage cropped for a few years, depending on the dynamics of economics and government policy. Considering Canada as a whole, there may be difficulty in maintaining present acreage. In fact, total farm area occupied in 1956, according to DBS, was already less than in 1951.

<u>Technology and Utilization of Cultivated Acreage</u>

Notwithstanding the measured land area in crop production, technology has, and will continue to have, a considerable impact on the net productive capacity of the improved acreage at hand. The most significant event in this direction was the nearly complete displacement of horses by tractors as the source of farm power. The effect this changeover had on the net productive capacity of our soils is well described by Downing:

> "In the west one tractor has replaced approximately 10.5 horses. In Eastern Canada the ratio has been 1 tractor to approximately 4 horses. This replacement has had two important effects on agricultural production. The first one is that it has released for the production of food and fibre for man approximately 10 acres per horse replaced in the west or over 100 acres per tractor presently in use. In the east there has been released approximately 3.5 to 4 acres per horse or 15 acres per tractor presently in use. In Saskatchewan alone this has meant approximately 9,000,000 acres, about half of which was cropland or hayland. In Ontario this has meant approximately 1,750,000 acres, two-thirds of which would be crop or hayland."

According to the Gordon Commission there still were 871,000 horses on Canadian farms in 1955[5] and by 1980, it is estimated the number will have declined to about 287,000[6]. Thus with a horse population in 1960 of about 571,000 it is likely that an additional 2.5 million acres presently supporting horses will be released for other purposes by 1980.

Much more significant, however, may be the impact of technology and agricultural extension on the institution of summerfallowing in the Prairie Provinces. Experience and experimental data have convincingly demonstrated the need for a high proportion of land in summerfallow in the Brown and Dark Brown soil zones of Western Canada. The same cannot be said, however, for the more humid areas of the Black, degraded Black and Grey Wooded soils which have similarly been subjected to the practice of summerfallowing. Although the reason for fallowing in these areas may be more as a measure of weed control than moisture conservation, this reason is also no longer valid in the light of available selective herbicides. The beginning of a trend toward longer term crop rotations in the Park Belt of the northern prairie region is already in evidence and is in keeping with the need for more forage crops for increasing livestock populations. Dion and the Gordon Commission[7] are in general agreement that this trend will be accelerated because of the increasing demand for livestock products. Both estimate that by about 1980 the present 30 per cent of cropland annually in fallow may be reduced by about half and thus

release an additional 6 million acres for cropping. Although a considerable portion of the impetus toward this anticipated reduction in fallow may be attributed to economic forces, nevertheless technological innovations such as more selective herbicides and the availability of improved tillage equipment for implementing more efficient moisture conservation practices will also play a significant role.

Technology and Intensification of Production

The general trend toward reducing summerfallow acreage in Western Canada may be conceived simply as the beginning of a long-term trend toward increasing over-all productivity by more intensively farming the acreage currently under production. The rate at which this intensification will proceed is a function of many determinants of which technological change is one. Some of the other more obvious factors are: size of population, relative demand for different farm products, standard of living, availability of farm capital and credit, efficiency of agricultural extension, available resources for fundamental and applied research, acceptance of responsibility for the food requirements of other nations, the state of international tensions, etc. Because of a dynamic host of interacting factors the problem of even attempting to isolate the implications of technological change for agricultural productivity is indeed a formidable one. For instance, a considerable change in the production pattern both in terms of kind and quantity could be safely predicted for Canada during the next 20 years irrespective of further technological change. Both Black and Bentley refer to welcome changes in crop production patterns as the elements of a frontier country gradually give way to a process of national maturation. They both suggest that Canadian agriculture is now in this period of natural transition. The direction of this change is fortunately toward a more stable and diversified system of which the most significant by-product is an increase of forage crops to meet the needs of an increasing livestock population demanded by a growing human population. This in turn provides for much needed soil conservation practices or indeed for the rebuilding of many soils that have been seriously weakened in structure and element during the many years of cropping and fallowing. Black suggests that prior to 1955 production increases in agriculture were reflected primarily in increased crop production whereas after 1955 expansion will be evidenced principally in livestock production.

Relative to this period of adolescence in the maturing process of Canadian Agriculture, Black made the following statement in 1960:

> "It would therefore appear that intensifying the agriculture on the land already in crops and pasture in the Central and Prairie Provinces, and stepping up the rate of application and development of technology on lands already being farmed will consist of nothing more than converting much of the wheat farming in the Prairie Provinces to feed grain and livestock farming and improving the related technology."

Inasmuch as this statement appears to point clearly to the general direction our agriculture will be taking during the next few decades the remainder of this paper will direct itself toward its analysis and clarification. For convenience of study the material has been separated into four areas.

I. The impact of technology on the productivity of land already in crops and pasture.

II. The impact of technology on the productivity of crops.

III. The impact of technology on the productivity of livestock and livestock products.

IV. Summary, Co-ordination, Projection.

I. The Impact of Technology on the Productivity of Land Already in Crops and Pasture

One obvious difficulty when dealing with topics of a prophetic nature is the foreknowledge of the likelihood of a considerable disparity between what could happen and what will happen. One of the main criteria determining the impact of technology on any form of production is the incentives provided the producer to incorporate technological innovations in his production program. It may well be that the application of technology could increase production materially but not enough to pay for the added cost. Thus, the impact of technology on land productivity is essentially a function of the incentives at hand and the efficiency of the extension program. This fact is brought out by Richards when he estimates that in

Eastern Canada only about one-third to one-half the production capacity of the soils was presently realized. Similarly Bentley suggests that "production of field crops could probably be increased by at least fifty per cent from the land now cultivated if all farmers followed recommended soil management and fertility practices." Bentley's implication is arresting. Usually a farm practice is not recommended unless it is economically justified. This then suggests that most agricultural producers forego about one-third of their potential production and income by neglecting only the soil management aspect of their production program.

By applying Bentley's estimate to average production and yield of wheat, oats and barley in Canada during the 5 year period 1956-57 to 1960-61 the additional production that could have been realized annually by the use of recommended soil management practices is indicated below[8].

Wheat..........222,212,000 bushels
Oats...........225,240,000 bushels
Barley......... 111,553,000 bushels

It is obvious that one of the most important problems to which Canadian agriculture must address itself is that of narrowing the gulf between possible and actual farm production. The root of this discrepancy obviously has several branches. Among these could be listed the lack of ready capital and credit. Such a lack, however, is often related to inferior managerial ability--which indeed may be the most significant of all factors. It would seem, however, that this problem is rapidly resolving itself by the gradual consolidation of smaller land holdings into larger units with more capital and better management. A further causal factor might also be that soil management extension lacks the resources, techniques, or understanding of motivating factors governing changes in farm practice. Whatever these causal roots, it seems obvious that the first step toward assessing our resources of tomorrow should be that of obtaining a clear understanding of our resources of today. Such a clear understanding requires that we know why our present resource potential is not being claimed. When Canadian farmers are annually denying themselves and the world over half a billion bushels of cereal grain--by neglecting only one farm practice--then it seems that the hierarchy of today's research priorities in agriculture are drastically out of step with

the needs. The fact that basic research in the field of agricultural extension might entail the use of a set of disciplines heretofore foreign to agriculture like philosophy, sociology and psychology, should not deter us from or invalidate such research.

Although the under-utilization of our soil resources is a basic problem common to all of Canada, there are regional differences that merit mention.

In Eastern Canada, where most of the agricultural land is of a podzolic or gleysolic nature, the crop production problems center about low pH, low nutritive level, poor drainage, excesses and deficiencies of moisture and other related imbalances. Richards shows how some of these imbalances are so pronounced that without remedial treatment only a small fraction of the possible crop yield can be realized. To illustrate, he produces experimental data to show that potatoes, when unfertilized, yield from one-third to one-half that obtained when using maximum recommended fertilizer rates. Potatoes are cited because they represent the most commonly grown intertilled cash crop in Eastern Canada. More important in terms of total crop production is the response of pasture and hay crops to corrective soil treatments. On Nova Scotia podzols hay and pasture yields on untreated soils were only 16 per cent of that obtained when recommended lime and fertilizer practices were employed as compared with 60 per cent on the Grey Brown podzols of Ontario.

Richards also estimates that about one-third of the improved land in Eastern Canada is imperfectly or poorly drained. He suggests that on mineral soils drainage improvement could effect yield increases in cereals from 50 to 100 per cent and in hay about 10 per cent. In most cases, however, drainage entails a costly tiling operation and thus economic considerations become determinant. After a thorough overall appraisal Richards then estimates, as mentioned earlier, that only "about one-third to one-half of the production possibilities of the soils of Eastern Canada are being realized". Stated differently this means that by employing technology presently at hand production could be increased by 100 to 200 per cent beyond that now realized. Obviously if the research he suggests as still being necessary could be carried out the gap between possible and achieved production would be still wider.

The factors limiting maximum crop production in Western Canada are in several respects quite different from those in the East. Because of the extremely low ratio of forage crops to total crop acreage in the West, Bentley states that "to date the soil management of most farms in Western Canada has been soil depleting and soil deteriorating". Generally these practices have been necessitated by the prevailing semi-arid climate with frequent requirement for summerfallowing along with the economic imperatives of the "wheat economy". The past 40 to 50 years of alternate cropping and fallowing have resulted in a serious depletion of organic matter and soil nutrients, a loss of productive top soil through wind and water erosion and a deterioration of the once excellent tilth and structure that characterizes grassland soils.

Because of the already apparent long term upward trend predicted in the demand for livestock products Bentley optimistically looks forward to a gradual reduction of many of the soil problems associated with the mono-culture presently prevailing in Western Canada. The additional hay, pasture and coarse grain acreages required to support a livestock industry will be integrated into soil conserving and rebuilding rotations on many farms across the prairies. Once such a trend is firmly established the 35 per cent of cropland annually in summerfallow may drop to about one-half that amount, with a consequent reduction in erosion and other associated problems. The effect of forage crops on overworked and overcropped soils can only be beneficial. Accompanying such intensification of production the economics of increased fertilizer use may become ever more advantageous and thus, with increased use, reduce the dependence on soil nutrients alone.

Although the use of fertilizer has increased steadily during the last two decades, Bentley estimates that more than half the farms in the West have not used fertilizer to date. In this a great production potential remains untapped.

In summary then, Bentley estimates that by applying present knowledge of soil fertility and management, crop production in Western Canada could be increased from 10 per cent to 100 per cent depending on the region. As an average increase potential he estimates approximately 50 per cent. In addition, the application of present management knowledge to the production of fruits and vegetables in British Columbia could result in increases approaching

100 per cent. Again these spreads would be considerably widened if research dollars could be invested in shedding more light on problems yet unsolved. Studies in this direction would concern themselves largely with moisture conservation and utilization, native pasture and rangeland improvement, and a host of nitrogen problems including fixation, availability and utilization.

It is, then, abundantly apparent from intensive studies by authorities on the soil of both Eastern and Western Canada that by the application of soil technology, crop production could be increased immensely. How much of this potential increase of 100 to 200 per cent in Eastern Canada and 50 per cent in Western Canada will actually be claimed by producers by 1980 is not known. This will depend largely on the many factors that govern the rate at which cropping intensity takes place. The economic incentives offered will, of course, have the greatest bearing. The fact should not be overlooked that these estimates are based entirely on technology presently ready for application. As more findings of research on soils accrue this untapped potential will obviously increase. How much greater this potential will be by 1980 than it is today is not known but it is safe to predict that the amount will be substantial.

II. <u>The Impact of Technology on the Productivity of Crops</u>

Inasmuch as wheat is perhaps the most publicized product of Canadian agriculture a popular misconception concerning the impact of technology on its recent level of productivity should first be corrected. Although the average wheat yield for the 10 year period 1951 to 1960 is about 20.5 bushels per acre as compared with a 16.4 bushel average for the period 1908 to 1955, this difference cannot be directly attributed to technology. When discussing the unusually high yields in the latter period (1951-55) the Gordon Commission says, "The yields of grain on the prairies are very dependent on growing conditions and in this respect, the exceptional growing conditions of the 1951-55 period are reflected in high average yields for wheat and barley in that period." The Searle Grain Market Features shows that these "exceptional growing conditions" continued throughout the second half of the fifties as well. The Searle report also shows that despite these "exceptional growing conditions" during the last five years, the total disposition of wheat was slightly greater than total production. The burdensome carryover, it is shown, was inherited from the

first half of the fifties, not because of higher yields, but because of an annual average of four million more acres seeded to wheat in the first half (26.1 million) as compared to the second half (22.1 million) of the fifties. The Searle report says that, "on this acreage approximately 425 million additional bushels of wheat were raised during the 5 crop years ending July 31, 1955." This amounts to the approximate equivalent of one (recent) average year's production. When considering the vagaries of nature and the dependence of an ever increasing domestic population on a continuous supply of wheat for both domestic and external use, a carryover of one year's production does not seem incongruent with the over-all national interest.

The intention of the preceding discussion was to dispel the myth that by the fruitful efforts of research scientists our grain yields have been steadily climbing and that the "ultimate yields" are as yet nowhere in sight. The facts do not bear out such a contention. Indeed the past experience has been that all the efforts of science spent on the improvement of cereal crops has been no more than a struggle to "hold the line" by warding off the "enemies" of production. Considering the need for plant breeders to be continuously pre-occupied with increasing the range of disease and insect resistance in commercial crops, very few plant scientists have had the opportunity to devote all their efforts toward increasing the inherent yielding ability of crop plants. That yields have not increased in past decades in spite of the unrelenting efforts of research is supported by the Gordon Commission[9].

> "Fluctuations from year to year in yields per acre in the Prairie Provinces are very great, but, even when these are overlooked, it is difficult to suggest that there is a trend upward in the yield per acre of any one of the three major grains."

This contention also implies that there are no apparent indicators to suggest that cereal crops of significantly higher yielding ability can be expected in the immediate future.

A similar view was expressed by Hamilton when he considered the technical barriers forbidding such an advance.

> "In the past 20 years we have done considerable

> plant breeding, yet we have been unable to produce a variety that has appreciably more yield potential than Thatcher. This may mean that we have reached the limit of yield potential or it could mean that our methods are too cumbersome to detect small increments which, in total, would represent an advance."

Such a conclusion, however, should not leave the impression that plant scientists have been unproductive and that the technological application of their discipline has not affected agricultural productivity. Nothing could be farther from the truth. Earlier it was stated that the chief occupation of those engaged in cereal improvement to date was to develop varieties resistant to competitive pathogens and insects.

Competition for the fruits of the soil is much keener in the field than it is in the market place. The plant scientist has been man's worthy and successful advocate in the ruthless struggle for survival between man and the other parasites of growing crops. Weir refers to these accomplishments of science in monetary terms as follows:

> "After Marquis fell from favor due to its susceptibility to wheat stem rust, the chief contribution of plant breeders has been their ability to develop new rust resistant varieties. A careful estimate for a twenty year period commencing in 1938 would indicate a farm income increased by 2.25 billion dollars for Western Canadian farmers as a result of rust research."

The above refers only to the dividends of research directed against one parasite attacking one crop in three provinces of Canada. Obviously then, $2.5 billion is but a small fraction of the total impact of plant breeding on the total productivity of Canadian agriculture. Scores of additional examples could be cited but are well known.

It seems then that conventional methods of plant breeding offer little hope for increasing the yielding ability of cereal crops, barring of course, an unforeseen breakthrough comparable to that of hybrid corn. This, however, does not preclude drastic changes in crop productivity during the decades ahead. Conventional

methods of plant improvement have already begun to give way to excitingly new approaches that appear now to offer future possibilities for an untold number of entirely new crops virtually tailor-made to specification. Hamilton and Weir both agree that the future employment of these new approaches offers the greatest possibilities for increased productivity.

When dealing with wheat specifically and when considering what is likely to take place in the way of improvement in the future, Weir deals briefly with several new approaches, the most significant of which is termed chromosome substitution. By involved processes the plant breeder is able to measure the effect of individual wheat chromosomes (basic carriers of heredity) on the productivity of a wheat variety, and systematically substitute superior chromosomes for inferior ones. In this substitution program, recent technological and scientific advances permit the plant breeder to introduce into wheat by replacement, individual chromosomes or even parts of chromosomes from different species or genera. As one example of how this may work, Weir states:

> "Assuming that a chromosome of winter wheat which contributes nothing toward hardiness is replaced with a chromosome of winter hardy rye which contributes more toward hardiness, it is theoretically possible to develop a wheat variety that has the combined hardiness of wheat and rye. It could even be hardier than wheat or rye."

He concludes with the prediction that:

> "The chromosome substitution method will undoubtedly lead to major advances in the next few years and may only be an intermediary step in the adaptation and utilization of entirely new grains."

The ability to create entirely new species of crop plants may provide a major breakthrough in crop productivity. As an example Weir cites the synthetic species already developed from a cross between durum wheat and rye. This species differs genetically from bread wheat in that the germ plasm of rye has replaced the goat grass plasm component of bread wheat. With this replacement

a very vigorous growing new species was produced. According to Weir "there now remains a period of adaptation and improvement until the new species can find a place in the crop production program." Of particular significance to the implications of technology on the future productivity of cereal crops is Weir's concluding statement on species building:

> "Even before the potential of these many species can be established individually, crosses are being made between them so that new species may be developed involving instead of two, three parental types. The untapped resources of this new potential reach fantastic proportions, because the process is one of recombination as well as addition and subtraction."

Since the aforementioned approaches toward the eventual increase of crop production are largely unproven, no estimates have been seriously put forward as to the production potential they embody. On a purely speculative basis, if winter wheats sufficiently hardy to be grown on much of the prairie farmland are produced and supplant spring sown wheats, at least a 20 per cent increase in yield could be expected. Even larger increases are anticipated from some of the new species that are currently being synthesized.

Research on fodder crops such as hay, silage and pasture has been slow in getting established in Canada. One reason for this may have been that until recently the extensive grassland areas readily available have in their natural state produced sufficient forage to carry the livestock population required for our domestic use. Nevertheless, Weir estimates that by the production of new varieties of alfalfa the use of this important legume has increased over-all forage production tremendously. He cites an estimate that over the last 40 years cultivated hay and pasture yields have increased by one-third of a ton per acre through the use of better varieties of grasses and legumes. On the basis of 21.5 million acres of cultivated hay and pasture in Canada, this increase amounts to about 6.8 million tons a year, or an increase in yearly revenue of about 100 million dollars. He notes, further that two-thirds of this increase has come about since 1945 and predicts we are only on the threshold of what can be done.

It is, however, unlikely that much will be done so long as pasturing and haymaking are considered as being the least intensive method of using land. A new trend may, however, be in the making. The Gordon Commission points out[10] that in areas where more intensive production has set in and land prices are high, better crop management practices and improved seed mixtures are used to raise the carrying capacity. This trend will likely diffuse throughout the country as we mature from a grain growing to a livestock agriculture.

It appears that in the foreseeable future the chief contribution of technology in forage crop production will be in matters pertaining to crop management rather than plant breeding. Studies indicate that we are far from realizing maximum production from the species and varieties presently available. Thus added yield potential achieved through breeding new varieties would be of limited value if it was lost by poor management. This concept is born out by the results of a three year pasture experiment concluded in 1959 at the University of Manitoba. When using dairy cattle, a rotation system of grazing was found to be about 30 per cent more productive than the conventional continuous grazing system. To date the importance of employing good husbandry on pasture and hay fields has not been generally recognized in Western Canada. Bentley emphasized this when he claimed that the areas of greatest productivity potential in the West are the rangelands and the pasture and hay fields on individual farms.

Exactly how great this potential is and when it will be claimed is not known. Obviously it will not be claimed until it is needed or until grassland farming becomes recognized as an intensive rather than an extensive form of agriculture.

Agricultural crops other than the cereals and forages are also certain to be influenced by technology in the decades ahead and thus influence the cropping pattern of Canada.

Constantly under study is the development through plant breeding of earlier maturing varieties of corn, soybeans, sunflowers and a host of other crops. A break-through with one such crop might well push back its northern frontier and change the agricultural landscape.

A major technological accomplishment that is certain to leave its mark is the recent discovery in Western Canada that the fatty acid composition of rapeseed oil is highly interchangeable. Already strains of rape have been isolated in which the 40 per cent of erucic acid with questionable qualities has been eliminated and the oleic acid component (the major constituent in olive oil) increased from about 17 to 60 per cent. This substitution now makes it possible to develop varieties of rape tailored to meet specific fatty acid specifications. It is significant that rape was selected for this initial study because no other oil bearing crop grown in Western Canada is capable of equalling its oil production per acre. Once varieties with specific oil characteristics are released for commercial production (which may happen within the next five years) the production of rape will certainly expand far beyond its present acreage. Since rape is best adapted to the more northerly regions of the prairies and since it competes with wheat for summerfallow, the production of wheat in those areas is likely to decline more rapidly than in southerly regions. Such a trend would be significant for two reasons. First, acreage would be taken out of wheat production where yields per acre are highest thus reducing total wheat production; second, the wheat taken out of production would be of lower protein content than that produced in southerly regions and thus effect a higher average protein content for our total production.

The next twenty years is also bound to produce great changes in the patterns of fruit and vegetable production in Canada. Technology in the field and in the food industry will continue to extend the supply of and demand for home grown truck and orchard crops. Already the factory processing of potatoes in pre-mash, frozen, french fry and "chip" from has called forth additional potato acreage and is changing the eating habits of many people. Similar changes are underway in most other areas of the food industry. To predict the nature of our eating habits by 1980 would be futile speculation. This is well illustrated by Nesbitt in his paper "Food Technology in the Sixties":

> "In my opinion the possibilities for the next ten years are absolutely fantastic. If you do not believe this consider for a moment what has happened in the last ten years. Fortune Magazine in a survey "Markets of the Sixties" outlined the major accomplishments in

> the last decade. Fourteen of these accomplishments were of a type which were totally unpredictable. Twenty-one were achieved much sooner than most experts would have expected. What has happened in the past ten years is equally true of the next ten years. Science advances in at least a geometrical proportion. One discovery leads to many other discoveries and we have a mushrooming effect."

This statement also points out the problem of arriving at a reasonable estimate of productivity by 1980 in any area of agriculture.

Special mention must be made of the impact of technology on pest control as related to crop productivity.

Many estimates have been placed on annual crop losses caused by insects, diseases and weeds. The future control of these pests by advances in technology could obviously affect our net crop output materially. An adequate discussion of past losses and the role of science in reducing future losses would warrant a full paper in itself. A few comments are, however, in order.

MacDonald estimates that the annual crop losses in Saskatchewan from only four insect species for the years 1926 to 1957 was about 10 per cent of total production. On the basis of an average annual grain production during this period of 367 million bushels, the loss would amount to about 36.7 million bushels annually from only four insect species on three crops in one province. When extending this concept to all destructive insects on all crops in all provinces the yearly losses would be enormous indeed.

MacDonald's data do show, however, that insect losses since 1950 have been about half those recorded prior to 1950. Obviously the grasshopper epidemics of the 1930's have a bearing on these data, but so has the ready availability of a wide range of selective insecticides. It is reasonable to expect that through the combined efforts of advancing technology and agricultural extension, crop losses due to insects will be gradually reduced. Insecticides are becoming more selective, more potent and less costly and the means of application are becoming more efficient and more readily available.

Entomologists point to control measures other than chemical that are also showing much promise for the future. Biological control (the spraying of insect disease organisms) is already employed in isolated cases and will doubtless be used to an increasing degree against those pests for which they are effective, and where they leave no undesirable residue on crops treated. Genetic means of control may also be developed. By this method large numbers of sterilized males are released and so reduce the numbers of future generations. It is believed, however, that the biggest effects on control of pests and disease will arise from advances in chemicals and physics and in methods of use. In addition, the close co-operation among entomologists, pathologists and plant breeders will insure that ever more crop varieties will have "built in" resistance to insect and disease attacks.

Some mention of crop losses through disease was made earlier in this section. Many indicators also point to a gradual lessening of crop losses caused by pathogens. An ever widening array of selective fungicides, paralleling that of the herbicides, is already apparent. Plant breeders, as mentioned, are on the attack on another front. In addition, a gradual changeover from a crop-fallow sequence to a longer cropping rotation including forages is bound to reduce the severity of many diseases and insects as well as weeds.

Annual crop reduction through weed competition is difficult to estimate but controlled studies and objective appraisals all point to incredible losses. In 1956 Anderson estimated an annual crop loss in Canada due to weed competition at $249 million. Wood estimated that of the 40 million acres planted to grain crops in Western Canada in 1955 about 14 million acres were treated with herbicides. Conservative estimates placed the grain saved through treatment at 10 per cent for wheat, 20 per cent for oats or barley and 40 per cent for flax. Thus, by treating just over one-third of the cereal acreage and reducing competition from primarily one weed, wild mustard, an additional 57 million bushels of grain worth about $60 million were recovered. Scores of weed species cause crop losses but none as extensively in Western Canada as wild oats.

In 1959 Foster found from surveys that at least 85 per cent of all cultivated land in the Prairie Provinces was infested to some degree with wild oats. Of this total about 70 per cent was of

medium to heavy infestation. Competition studies in Saskatchewan revealed that on even a medium infestation barley yields were reduced by 16 per cent, wheat yields by 33 per cent and flax yields by 84 per cent. These data support other estimates that the annual crop toll of wild oats may be well over 100 million bushels.

The age-old battle with the elusive wild oat seems to be drawing to a close. Nineteen sixty marked the first year of commercial use of a wild oat selective herbicide. A careful study of 151 commercial fields of wheat so treated showed an average yield increase of 9.2 bushels per acre over non-treated strips. It seems that earlier loss estimates have been vindicated--if not indeed proved too low.

As these herbicides are produced in greater volume with consequent price reductions it is safe to predict that an ever greater acreage will be treated. The impact on crop productivity is obvious.

Similarly, technical advances in the control of scores of other weeds in forage crops, corn, rape, vegetables, fruits, oilseed and many other special crops is bound to effect an increase in net production in the years ahead.

In the foregoing discussion an attempt has been made to foresee some of the future trends in crop productivity apart from the influence of fertilizers and soil management. Indications are that in cereal and forage crops conventional approaches to plant breeding may have but a negligible influence in upgrading inherent yielding ability. Recent advances in genetics, however, open the way for a recombination of desirable components of existing plant species so that the ultimate effect on over-all productivity could be considerable. How much of this effect will be apparent by 1980 is not known. In forage crops a great immediate potential is possible by the improvement of crop management practices. Similarly, by the combined advances in plant breeding and crop husbandry, vegetables, fruits and special crops will undoubtedly keep pace with other crops in the constant striving to "make two blades to grow where only one grew before". Most clearly in focus, however, of all future effects of technology on crop productivity is not so much the production of more crop, but rather the harvesting for man of a greater proportion of what is being

grown. This will come about by a steady improvement in our implements of warfare against our enemies in the field--the pathogen, the insect and the weed. This in itself could amount to many thousands of additional tons of crop per year.

III. The Impact of Technology on the Productivity of Livestock and Livestock Products

Livestock production is rapidly attaining a dominant position in Canadian agriculture. In Eastern Canada this has been the case for some time. The Gordon Commission predicts[11] that by 1980 Western Canada will also be dependent on livestock and livestock products as the major source of farm income. The Commission also shows that in the past the physical volume of livestock and livestock products has increased at a rate closely paralleling the increase in population. If the forecasts of a steady rise in standard of living can be accepted, then the future rate of livestock output may slightly exceed that of population increase. In terms of total consumption of livestock and livestock products by 1980, the Gordon Commission predicts an increase of 204 per cent over the average consumption during 1951-55. Although actual production and consumption predictions have no direct bearing on this discussion their brief consideration does provide perspective for a better appreciation of technology and its possible implications.

Technical progress of no lesser magnitude than that discussed in the previous section has also been made in livestock and poultry production. Most of this progress can be attributed to a combination of factors including breeding, improved nutrition, management and disease control. The Gordon Commission[12] cites the following instances of continuing production efficiency. From 1947 to 1955 egg production per hen in Canada increased by 15 per cent. Average milk production per cow increased from 1935-39 to 1955 by 29 per cent.

A much more comprehensive account of the recent impact of science in animal productivity is quoted from Weir:

> "Hybridization and the formation of new breeds and strains already have resulted in modern broiler production efficiency, where two pounds of feed are needed to produce one pound of broiler, and where an average of two hundred and sixty eggs per hen housed,

are a reality. Application of known principles could have similar gains in livestock. Swine breeding experiments have shown that a two hundred pound pig can be produced in four months with as little as two and one-half pounds of feed for each pound of live pork produced. Calves of over six hundred pounds at six months of age have been produced compared to an average of four hundred pounds or less. Gains of four pounds per day in beef cattle on feed are possible which is nearly double what is being achieved in the field. Even though dairy production has essentially doubled per animal unit in the past fifty years, it seems quite feasible that further doubling is possible in the foreseeable future. Many cows produce upward of twenty thousand pounds of milk a year and it should be possible, using the best scientific procedures to achieve such production on a herd basis, even on a national basis."

Jacobs refers to the same general trend by citing an Indiana experiment in which one group of steers were fed on a 1908 ration and another group on a modern ration. The 1908 ration has a feed conversion of only 10 to 1 whereas the modern ration had a conversion of 6 to 1. The daily gain in the modern ration was also about 40 per cent better.

In addition, Jacobs states that:

"Currently in North America we produce about 50 per cent more beef from the same number of animals than we did 30 years ago. This is achieved mainly by grain-finishing a far larger percentage than we ever did before, by selling cattle at a much younger age, by higher percentages in calf crops and by a great reduction in death losses of one kind or another."

When considering the present state of technological achievement along the entire livestock front Weir concludes as follows:

"It is estimated that application of all the scientific principles of breeding, feeding and management, as well as disease control, could result in doubling the

> livestock products using the same amount of feed units as at present."

As in all previous instances the unknown factor is the rate at which these scientific principles will be employed for commercial production.

Again, as mentioned when discussing soil and crop productivity, the finger of science in animal biology is pointing in directions all around us, which if thoroughly explored by intensive research could lend to a productive potential beyond our fondest hopes. However, research in animal science is costly because of the need to keep large flocks and herds for breeding and nutrition research and furthermore, by the very nature of the science, conclusions are often slow in coming. Rather than cause a retraction in research these factors should call forth more funds and more intensive effort.

According to Weir one of the greatest advances of recent decades is the freezing and storage of semen and the commercial use of artificial insemination. To date this has resulted in the possibility of a particular bull becoming the sire of as many as 25,000 offspring per year of his reproductive life. Research in this field is continuing in a wider range of animals. It is, however, unfortunate that commercial importation and use of semen for artificial insemination is presently being hampered by the undue influence of the purebred breed associations in determining import and tariff regulations.

As most important avenues of future animal science research Weir lists such areas as Mechanism of Inheritance, Statistical Genetics, Immunogenetics; Biochemical Genetics and Physiology of Reproduction.

Inasmuch as agricultural production in all regions of Canada is rapidly becoming more livestock oriented, increasing support for education, research and extension in this direction is essential. The importance for such support was well stated by Weir as follows:

> "Producers at the present time, due to economic competition are hungry for information from

experimentation which can be used to increase their profits. It is important that the experimental work progress and it is also important that dissemination of the information at a practical level be speeded up. Poultry and animal breeding research is moving forward in Canada. Research activity has speeded up considerably in the past decade. More highly trained men are available than ever before. The future is bright and the potential is tremendous if sufficient funds and facilities are made available. Support for research, education, extension and application has been improving. The result cannot help but be a tremendous improvement in the efficiency of production of livestock products, meat, milk, wool and eggs."

Notes and References

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1 Throughout this paper reference to the "Gordon Commission" refers, in fact, to the volume, Progress and Prospects of Canadian Agriculture, written by W.M. Drummond and W. MacKenzie, and authorized for publication by the Royal Commission on Canada's Economic Prospects.

2 *Ibid*., p. 227.

3 Improved land is applied to land which has been "once subject to plowing."

4 Drummond and MacKenzie, *op. cit*., pp. 62, 64.

5 *Ibid*., p. 100.

6 *Ibid*., p. 106; 1951 population 1,304,000.

7 *Ibid*., p. 73.

8 Dominion Bureau of Statistics.

9 Drummond and MacKenzie, *op. cit*., p. 82.

10 *Ibid*., p. 85.

11 *Ibid*., p. 92.

12 *Ibid*., pp. 87, 88.

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DISEASE AND PEST CONTROL

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A sound program for Canadian agriculture and for the use of available agricultural resources must include provision for effective, economical control of the many weeds, diseases, insects and other pests that adversely affect crop production. Such measures are essential even for crops of highest quality and yielding capacity, and even with the use of the best cultural or other production methods, whatever the region, climate and weather, and soil conditions under which the crop is produced. These measures will become increasingly important as demand for agricultural products rises, and especially when it becomes necessary to secure maximum possible production from those land and other renewable resources that are available. Not only that, but they are essential for the most efficient use of land and labor even now. In addition, solutions will be required for problems created by new pests and diseases as new crops are grown and as agricultural practices change.

The problems created by weeds, pests and diseases are many and varied in nature. At least 1,000 species of weeds, 2,500 insect, mite and nematode pests, 2,000 plant diseases, and about 200 to 300 parasites and diseases of livestock and poultry occur in Canada. Most of these are of very limited, or occasional, importance, but several kinds of weeds, diseases, insects and other pests may seriously affect the production of every kind of crop, and several diseases and parasites may similarly reduce the productivity of livestock and poultry. New pests and diseases appear every year. Most are of limited importance, but one or more usually become a problem in some crop. Domestic plants and animals must be protected from pests from planting or birth to

marketing, and their products until consumed or no longer usable. The problems differ with the crop, district, soil, climate and weather, cropping practices and agricultural history of the farming community. But research and practical experience have provided the knowledge which, if generally and effectively applied, would prevent most or all of the losses caused by these organisms, with corresponding economic benefits to the industry. Indeed, present levels of production are possible only because of control measures in use. There is some justification for the belief that with effective general application of present knowledge about pests and their control present levels of production might be achieved with about two-thirds the acreage and breeding animals now in production, or that production of the acreage now in use could be increased by almost one-third. In any case, an increase of 10 to 15 per cent in productivity should be possible within the next twenty years through improved control measures. At the same time this would result in less variability of production from year to year except for that directly attributable to weather, thus leading to greater stability in income and more uniform flow of produce to market. Because pests and diseases have demonstrated a remarkable ability to overcome the measures developed for their control, continuing research is required to maintain effectiveness of control measures, and to develop new ones for new problems, and more effective, lasting and economical ones for many of our present problems. Pest control will not increase the available agricultural land, but by preventing serious damage or destruction of crops it ensures that the potential productivity of any crop grown will be attained.

Cost of Weeds, Pests and Diseases

Various estimates have been made of the average annual losses of crops caused in Canada by some weeds, diseases, insects, and other pests of plants and animals, and of their products. Some of these are little more than informed guesses, or are generalizations without data; others are based on actual differences in yields between infested or diseased crops and comparable crops in which damage was prevented. An estimate[1] in 1955 by experienced scientists and administrators conversant with pest problems has placed the average annual loss of income from plant crops in Canada caused by weeds, diseases, rodents, insects and other pests and the cost of control at $1,100 million. Another $200 million to $300 million loss of income could be attributed to pests and diseases of

livestock and poultry. Thus, the total annual cost of pests and diseases in Canada amounts to $1,300 million to $1,400 million — an amount equivalent to about one-third of the annual agricultural product. Were no pests or diseases present and no control measures needed, the average annual income per farm would be increased by $2,300 (based on 575,000 farms). Even if an average increase in productivity of only 15 per cent were realizable, and half of the saving were spent on control, the average annual income would still be increased by $500 per farm. Since these estimates of losses were made, improvements in controls and their more general use have reduced crop losses caused by pests and diseases. Losses are still of such substance, however, that the improvements do not materially affect the estimate of potential savings over the next 20 years.

The reduction in crop yield and dollar losses from competition by weeds was estimated at about 13 per cent and $330 million by J.E. Wood in 1955,[1] and at 15 per cent and $311 million, plus $157 million for control measures and other miscellaneous costs, by Anderson in 1956.[2] Recently, G. Frieson and L.H. Shebeski[3] estimated the average reduction in yield of cereals in Manitoba at 14 per cent. This was based on differences in yields in weedy and weed-free plots in 142 fields representative of Manitoba conditions during the three years 1956-58, even with relatively extensive use of herbicides and of tillage for weed control. Even where herbicides had been used, the average reduction in yield due to weeds was 10.1 per cent. Other studies[4,5] showed that in addition to the reduction in yield, weeds significantly reduced the protein content of wheat, and that this occurred even where fertilizers were used, though the fertilizer reduced the loss in yield.

Comparable losses and costs are thought to be attributable to weeds in row crops of corn, soybeans, potatoes, vegetables, and in cultivated and native pastures and forage crops. In row crops much of the loss is for cost of cultivation and hoeing rather than from reduced yields.[2] In some vegetable crops costs of cultivation and weeding may exceed $100 an acre, but where one cultivation provides effective weed control the cost is about one dollar per acre. The annual cost of weed control in all row crops has been estimated at $1.8 million.

Damage by plant diseases varies greatly from year to year

but is usually most severe during and after periods of high humidity or rainfall that coincide with an abundance of disease organisms, as in the case of apple scab, late blight and rusts. Average annual crop losses have been estimated at about $200 million.[1]

From 1925 to 1935 cereal rusts reduced wheat yields in Manitoba and Saskatchewan on the average by 35 million bushels, or about 11 per cent of the possible yield. When to this is added the loss from lowered quality of harvested grain, the monetary loss amounted to $33 million annually.[6] From 1940 to 1949 the growing of rust resistant varieties of wheat reduced losses from rusts to insignificance. Then leaf rust and a new race - 15 B - of stem rust caused total losses of 204 million bushels of wheat in the three years 1953 to 1955[7] with most of this in 1954. Since that time losses have been small as a result of the growing of Selkirk, Lee and Pembina wheats, which have proved resistant to prevailing races of rusts.

I.L. Conners[8] has estimated that annual percentage reductions in yield of wheat, barley, oats and corn from smut are 1.2, 3.0, 3.4 and 2.0, and that these losses have not changed much in the past three or four decades. He also reported that a ten-year study by B.J. Sallans in Saskatchewan indicated that common root rot reduced the yield of wheat about 10 per cent.

A great variety of fungus and bacterial diseases also are serious problems in the production of fruits and vegetables, but losses attributable to them are not well documented. However, one or two examples may be sufficient to indicate the effect that diseases may have on production. In 1951 late blight of potatoes caused a loss of about one million bushels of potatoes in Prince Edward Island because the crop had not been adequately sprayed with fungicides.[8] This disease must be controlled throughout the season in nearly all parts of Canada if satisfactory yields of potatoes are to be obtained. For the same reason apples must be continuously protected every year by sprays against apple scab. Crops of lettuce, carrots and celery have been severely damaged or completely destroyed by aster yellows virus disease on several occasions, and in 1957 this disease also caused an average reduction of about 15 per cent in the yield of flax in the Prairie Provinces.

The annual loss of crops in Canada caused by insects, mites and related pests has been estimated to be about $300 million, or 10 per cent of total production.[1] Of this, about $200 million is for damage and destruction of plant crops and about $100 million for reduction in productivity of livestock and poultry from unthriftiness and mortality caused by various pests. In addition, losses in storage of agricultural produce and products caused by stored produce pests amount to about another $100 million.

The importance of insects as destructive pests of plant crops is illustrated by the estimates of losses caused by the wheat stem sawfly, wireworms, cutworms, and grasshoppers in Saskatchewan since 1926.[9] In the thirty years, 1926 to 1955, these pests caused an annual reduction in crop yield and value of 11.6 per cent and $29 million.[10] Percentage reductions in yield ranged from 5 per cent in 1956 to 33 per cent in 1938. In 1938 widespread and severe outbreaks of grasshoppers caused most of the loss, but substantial losses were caused by each of the other pests. In addition to the four pests mentioned, aphids on grain, climbing cutworms and other caterpillars on flax and rapeseed have caused severe crop losses in some years. The combined loss in Manitoba and Alberta was about equal to that in Saskatchewan. Reliable, comprehensive estimates of damage by insect and related pests to fruit and vegetable crops are not available. Records from experimental studies and observation, however, indicate that these are similar in magnitude to those for field crops. At times some insect pest has nearly ruined the fruit and vegetable industry. For example, the apple industry was nearly ruined in the late 1930's when control measures of the day failed against the codling moth. Root maggots at one time so severely damaged rutabagas in the Maritime Provinces that growers shifted to other crops. Before the advent of modern insecticides table potato production was possible only on wireworm-free land because in infested land wireworms rendered most of the potatoes unfit for consumption. Many other examples could be mentioned. The production of these and most other vegetables and fruits is possible only because effective control measures are in general use that keep losses at nominal levels. But, in spite of this, individual growers still experience severe crop damage every year from infestations by some insect pest.

Losses in livestock production from unthriftiness, lowered production of milk or lowered weight gains, and mortality resulting

from attacks on livestock and poultry by a variety of blood-sucking pests have been placed at $100 million annually.[1] These are from reduction in the value of hides and meat, injuries and reduced milk production resulting from gadding, etc., caused by cattle warbles, unthriftiness and lowered milk production caused by biting flies and lice, mortality and illness caused by ticks and flesh flies, and diseases such as equine encephalitis transmitted by insects. Often the cause of the loss is not recognized and is attributed to other causes.

Examples of the importance of diseases in reducing the productivity of livestock and poultry are well known. The outbreak of foot and mouth disease in Saskatchewan in 1951-1952 that in-involved only 1794 animals and 42 premises was eradicated within a few months at a cost of about one million dollars.[11] But the drop in market value of livestock from loss of markets cost Canadian farmers $648 million.[12] Brucellosis has been estimated to cause annual losses of about $9 million.[12] Every year approximately 0.5 per cent of the carcasses of animals slaughtered are condemned because of some pathological condition. In addition, mortality and unthriftiness from internal parasites and many diseases reduce production in many herds of livestock and flocks of poultry. Among the more important of these are mastitis in dairy cattle, coccidiosis, bronchitis, Newcastle disease, and common respiratory disease in poultry. At one time about 9 per cent of the cattle were infected with tuberculosis, but now this disease is extremely rare because of the eradication program. From time to time outbreaks of hog cholera occur in Canada, but prompt isolation of infected premises, eradication by slaughter of infected and contact animals, disinfection and isolation of affected premises and equipment, and other sanitary measures have in each case eliminated the disease within a few months.

Rodents cause about as much loss of crops and produce as insects. The species of rodents, type of damage, and losses have been discussed in some detail by W. Lobay,[1] who estimates that collectively these pests cost Canada at least $300 million annually. Richardson's ground squirrel (gopher), estimated to have averaged 40 per acre in the 1940's, destroyed up to 15 million dollars' worth of grain, vegetables and forage crops in the Prairie Province in some years. In recent years damage has been light because gophers have been scarce. Meadow and dear mice also destroy

much grain, especially when it is left in swaths in the field over winter; they also damage vegetables and girdle fruit trees.

In addition to the field pests, the Norway rat and house mouse cause enormous losses of all kinds of produce and processed food in storage. According to Lobay, a rat eats 5 dollars' worth of food annually and causes another 15 dollars' loss in wasted produce and from damage to buildings and food containers.

Crop Savings Resulting from Control of Pests and Diseases

Reliable information on savings resulting from control measures used to combat pests and diseases is even more scanty than data on losses because potential productivity in the absence of damage by diseases or pests is not readily determined. Most information available is from small plot experiments where treatments are compared with untreated plots. A few examples of increased production or savings attributable to control measures for a few pests and diseases illustrate what can be achieved.

The savings resulting from tillage, fertilization and other cultural practices used for weed control are not well documented for field crops but are substantial. In corn a single cultivation giving complete control of weeds increased yield of silage corn by 5.4 tons per acre, and in soybeans, 2,4 and 8 cultivations, respectively, increased yields 7.7, 14.2 and 24.2 bushels per acre[13] over crops that were not cultivated. Savings up to $100 or more in reduced labor costs have been obtained in vegetable crops where one or two herbicide sprays gave complete control of weeds.

In grain crops the returns from herbicide treatments are well documented.[14] In 1953 expenditures of about $6 million for herbicides for treatment of 12 million acres increased the value of the crop harvested by $32 million.[13] On this basis the increase in value of the crop harvested on 22 million acres treated with herbicides in 1960 at a cost of less than $8 million for chemicals was $58 million, and for the 14 years 1947 to 1960 that herbicides have been in general use the increase in production was worth $460 million. Surely the contribution by chemical weed control to increased production is substantial and steadily increasing.

In the six years 1938-1943, rust resistant wheat varieties are estimated to have increased annual production in Manitoba and

Saskatchewan by 41 million bushels valued at $27 million.[15] According to C.H. Goulden,[16] during the period 1938-1952 when Thatcher wheat was resistant to stem rusts, it increased annual production on 20 million acres in Manitoba and Saskatchewan by 100 million bushels over that which would have been produced by Marquis. According to L.B. Siemens,[17] this represents a saving or $110 million annually. If similar savings resulted from the use of Selkirk and other rust resistant wheats from 1956 to 1960, the total crop saved in the 20 years has added $2,250 million to farm income. Somewhat similar increases in yield have resulted in years favorable for the wheat stem sawfly from the use since 1947 of the sawfly resistant wheats, Rescue and Chinook, on up to 3.3 million acres in western Saskatchewan and eastern Alberta.

In Saskatchewan savings in 1949 and 1950 attributed to chemical control of grasshoppers were about $90 million for an expenditure of $2.1 million for chemicals.[10] Every dollar spent on chemicals returned $42.40. Similar and even greater returns per dollar expended for grasshopper control have been obtained in subsequent years.

Data supplied to the author by the Alberta and Saskatchewan Departments of Agriculture indicate that in 1953 seed treatments for the control of wireworms on 1.4 million acres at a cost of 1.25 million dollars increased production of wheat by at least 7 million bushels. Similar and even greater annual increases in production can be attributed to the use of seed dressings for wireworm control every year since that time. At the same time cost of the treatments has been reduced to about one-fourth or one-third that in 1953.

Production of most vegetable and fruit crops is generally possible only where insects, mites and diseases of these crops are controlled. Thus, much of the production of these crops may be credited to control of their diseases and pests.

Eradication of bovine tuberculosis in Canada, completed in 1961 at a total cost of 50 million dollars, has reduced incidence of the disease from an average of six per cent in 1928-29 to 0.087 per cent in 1959-60.[18] Thus, a serious cattle disease that also may affect man has been virtually eliminated. Similar eradication programs for Brucellosis and Johne's disease have already made

substantial progress and are expected to eliminate these diseases within a few years. Other measures for the control of other diseases and parasites of livestock and poultry, and the exclusion of serious diseases, have made equal or more valuable contributions to animal production in Canada.

The above examples indicate that, although pests and diseases reduce agricultural production by possibly one-third on the average, the use of crop varieties resistant to rusts, smut and the wheat stem sawfly, and of chemicals against weeds, grasshoppers, wireworms and cutworms, has accounted for at least one-fifth of the grain produced in recent years and a smaller though significant proportion of hay and forage crops. Also, perhaps one-half or more of the fruit and vegetable production, and in the case of apples and peaches nearly all the production, was achieved as a result of pest and disease control. The contribution of pest control measures to animal production is difficult to assess but is probably similar to that for grain crops. Thus, it is evident that disease and pest control practices have a vital role in agricultural production, and with more effective and more general use will make considerably greater contribution towards the realization of the potential productivity of most of our agricultural crops.

Importance of Pests and Diseases in the Near Future

The principal hazards from pests and diseases to crop production in Canada in the foreseeable future are likely to be presented by those pests and diseases that are already present and requiring control. Their relative importance is unlikely to change materially.

Nematodes, hitherto of only occasional importance, may be expected to become more important as pests of many crops. Virus diseases are either becoming more common or went unrecognized formerly in both plants and animals. As better knowledge of these diseases is obtained and as measures to combat them are developed, corresponding benefits in yield and quality of the crops involved may be expected.

Past records indicate that every year about five foreign insect pests and some nematodes and diseases new to Canada will become established. Fortunately, most of these will be of minor importance, but perhaps one in 20 may become a serious and wide-

spread pest of some crop or domestic animal. The face fly, an old-world insect first found in Nova Scotia in 1951, had spread as far west as South Dakota by 1960. It has become an abundant and annoying pest of cattle in Eastern Canada. The alfalfa weevil and European chafer are examples of forage crop insects that have not occurred in Eastern Canada though present in the Eastern United States, but which, once established, would create new problems in maintaining alfalfa and grasslands in a productive state. Potato wart disease (now in Newfoundland) and the golden nematode, if introduced into potato growing areas of mainland Canada, could ruin the industry and force the adoption of quarantines, rotations and control practices not now needed.

At least 60 insects, several nematodes, and some diseases of plants in Europe and Asia but not in Canada could, if introduced into districts with climates similar to their homeland, become a problem. In the case of plant diseases, the main threat is not from new diseases but from the development of new virulent forms of those now present. The accidental introduction of pests and diseases of man and animals from Eurasian areas could also create serious new health problems for man and animals.

Ocean-going ships that discharge cargo at inland ports in agricultural areas along the St. Lawrence Seaway have increased the chances of introducing pests over earlier days when trans-atlantic trade was between maritime ports. Jets fly between global airports in agricultural districts with crops and climates similar to our own but with pests not yet in Canada. Insects such as flies, mosquitoes, and adults of white grubs that enter the air-craft can survive the trip of a few hours and escape on landing in Canada, whereas they would normally perish during the much longer trips taken by surface carriers. Normal disinfestation and inspection practices provide assurance that few insects will escape; yet, in time, escape and successful establishment of new pests is bound to occur. To keep such occurrences at a minimum, inspection and disinfestation procedures established under regulations of the Destructive Insect and Pest Act and the Animal Contagious Diseases Act should be fully maintained and strengthened as needed.

A new crop free from pests when introduced may acquire pests or diseases that occur on related plants within a few years. This has been the case with rapeseed. In the first few years of

its production in Western Canada, diseases and insects were of little importance. As production continued and acreage increased, flea beetles, various caterpillars, aphids, root maggots, and some diseases became more prevalent and occasionally destructive. As any new crop is brought into production the situation described above is likely to be repeated.

Status of Knowledge of Pests and Diseases and Their Control

The examples given above demonstrate that pests and diseases are important constant factors tending to reduce seriously agricultural productivity, often to the verge of disaster for many producers, and that practices to prevent or greatly minimize these losses are an integral part of a modern, efficiently operated, highly productive agricultural industry. Experience has also shown that these problems are not static, but are continually changing; every new crop, new variety of an old crop, new rotations, new types of machinery or methods, increasing mechanization, changes in demands by industry and consumers, the increasing demand for produce uniform in appearance and high in quality, and growers' demands for more effective and cheaper controls, all create new problems for which solutions are required. Even the introduction of a new control practice may create or reveal another problem. Pests or diseases are rarely eradicated; they are usually controlled only sufficiently to prevent serious crop losses. The requirements for research are never-ending, for as a problem is solved, others take its place.

The number of weeds, pests and diseases and their importance have increased tremendously as settlement proceeded westward and northward, until most of the area suitable for agriculture was occupied, and large acreages were devoted to monocultures that provide ideal conditions for serious outbreaks of diseases and pests. Many native species became important pests of cultivated crops and livestock. Weeds, diseases, and insects from other areas, brought in with produce, plants, and animals, and by commerce, also gradually became established, and many have become important pests wherever conditions were suitable for their survival.

Research on pest problems in Canada began a little over 100 years ago with studies of the identity, taxonomy, life history, economic importance, and control of insects. Chemical controls were then virtually unknown; rotations, cultural and other farm

practices, though useful against weeds, were of limited value against most insects and diseases. As a result, severe crop losses caused by insects and diseases were common and often disastrous. Then, about 80 years ago, the first practical chemical control of a crop pest in Canada was obtained with the application of Paris green against the Colorado potato beetle. Soon afterwards Bordeaux mixture came into use for the control of late blight of potato and apple scab, and at about the same time Pasteur developed the first successful vaccines for protection of livestock against rabies and anthrax. These developments were the real beginnings of crop protection practices as we know them in Canada and elsewhere.

From then on investigations on pests and diseases and their control have greatly increased and have become increasingly fundamental and comparative in character in the last 15 or 20 years. Extensive knowledge of the pests, their identities, distribution, life-stages and life-processes, host relations, food and shelter requirements, the factors governing abundance, and ecological relationships, has been gained. From this information biological and chemical control measures have been developed and improved as knowledge permitted. Chemicals have become the main means of controlling most insects and many diseases, and in the last 15 years herbicides have become the most effective means of combatting weeds in growing crops, though cultural or tillage measures are still extensively used. Resistant varieties, developed largely since the 1930's, are the main means of combatting several crop diseases. Resistant varieties of wheat provide excellent control of stem and leaf rusts of wheat and the wheat stem sawfly. In other crops resistant varieties have reduced the severity of infections by many diseases and of infestations by a few insects.

Until the middle 1940's, a few inorganic chemicals of general toxicity, mineral oils, and the botanicals - nicotine, pyrethrins, and rotenone - were the chief pesticides available. Many important diseases and insects, e.g., rusts, root rots, wireworms, were not controlled by them, and they provided only mediocre to poor protection against many other pests. They were most useful against pests of horticultural crops and in baits against grasshoppers and cutworms. By this time pesticide application equipment and methods had been developed from the earliest laborious and inefficient hand methods to aircraft spraying and dusting. Prototypes of modern

automatic air-blast concentrate orchard sprayers and of low-volume boom sprayers also had been developed, though they were improved and modified more recently until today large areas can be treated quickly and uniformly. Thus, much of the drudgery and unpleasantness of pesticide application has been removed, with considerable savings in material and labor. Comparable advances have been made in insecticide formulation, which range from dusts, wettable powders, emulsions, solutions to fumigants, aerosols, and granules, each for particular purposes.

Since the introduction in the 1940's of the potent insecticide DDT, the herbicide 2,4-D, and the antibiotic penicillin, a large number of highly effective synthetic organic insecticides, fungicides, herbicides, and antibiotics have replaced most of the earlier pesticides and have greatly increased the effectiveness and practicability of chemical controls. Now, serious infestations and damage by most insects and many plant and animal diseases can be greatly reduced or prevented by the use of one or more resistant crops, cultural and biological measures, and pesticides.[19]

The new synthetic pesticides and antibiotics have created new problems: insecticide residues in food, resurgence of insects and mites after treatment because natural enemies have been eliminated, and the development of resistance to initially effective chemicals by many mites and insects, and to antibiotics by animal disease pathogens. Fungus disease organisms also have strains virulent to resistant varieties. Solution of these and many other problems is being increasingly sought by means of fundamental studies in physiology, biochemistry of life processes, host relationships, immunology, genetics, and population dynamics. From such studies rational and more permanent controls should result.

Because foreknowledge of the expected incidence and severity of pests is important to the effective use of control measures, forecasts and reports on outbreaks of many pests and diseases are prepared regularly. The most useful forecasts in Canada of pest outbreaks are those of the intensity and extent of grasshopper outbreaks in the Prairie Provinces made every fall for the past 30 years. They are based on systematic quantitative surveys of adults and eggs, and have provided essential guides for the purchase and distribution of insecticides, and for the planning and conduct of cultural and chemical control. These surveys are

expensive and time-consuming. Recent studies indicate that eventually reliable forecasts may be made from limited surveys and weather data at a small fraction of present costs. For most other insects and diseases advice on timing of control measures is provided by short-range forecasts based on field sampling, catches in traps, knowledge of previous abundance, and the effects of weather on abundance and rate of development of the organism. Improvement in forecasting insect or disease outbreaks is highly desirable, but is likely to depend on the development of more accurate long-range weather forecasts.

Several insects, e.g., the corn earworm, the potato leafhopper, the green bug, and the leaf and stem rusts of cereals, do not overwinter in Canada but do so in the southern United States. The insects or rust spores are carried into Canada often beyond agricultural areas by northward-moving warm air masses that coincide with flight or spore discharge. From knowledge of the overwintering places, when flights occur, and the movements of warm air masses, supplied by American entomologists, the appearance of these pests in Canada can be predicted and confirmed by trapping or by surveys, thus providing a basis for control recommendations. Should rust-resistant varieties of wheat fail and chemical controls become available, these records would provide a basis for timely recommendations for chemical control.

A related problem, that of determining the relationships between pest abundance and damage and the influence of weather and stage of crop development on it, has not been adequately studied in Canada for most pests, though such relationships are roughly known for the important species. There is a need for intensive quantitative studies of these aspects to provide a firm basis for research needs and for advice on control.

Modern disease and pest control measures may be separated into: (1) Management, cultural and sanitation practices; (2) The use of crop varieties resistant to pests; (3) The use of biological control agents (parasites, predators, and disease organisms); and (4) The use of chemicals. At one time cultural measures and sanitation measures were the chief means available. Today greater reliance is placed on resistant crops and chemicals, though cultural and management practices are still very important crop protection practices.

1. Management, Cultural and Sanitation Practices. Many practices normally used in crop production have proved useful in preventing or destroying infestations of various pests, providing valuable control at little or no cost. Sometimes only minor changes, such as a change in timing, are good control measures. Most changes have been developed through research on the life history of the pest which revealed a vulnerable stage and a procedure effective against it. Thus, in Western Canada, the practice of summer fallowing, primarily intended for moisture conservation, is a highly effective means of pest control, providing the principal means of weed elimination, preventing the egg-laying of grasshoppers and, by leaving an undisturbed crust during moth-flight of the pale western cutworm, preventing egg-laying and infestation in the succeeding year. By delaying seeding of fall wheat in Ontario slightly, infestation by the Hessian fly is avoided.

On the other hand, changes in production practices sometimes bring about new pest problems. Under irrigation, insects such as mosquitoes and horse flies, diseases and weeds favored by better moisture, become troublesome, while dryland pests become less important. Shallow tillage and strip-farming, introduced in the 1930's to overcome soil drifting, increased survival of the wheat stem sawfly and grasshoppers and also increased infection by common root rot over that of mould-board plowing. The use of the combine resulted in greater losses in harvesting wheat than with the binder because it stood so long that wheat stem sawfly breakage of straw had time to occur. The recent trend to grow corn for two or more years in succession is resulting in severe infestations and damage by the southern corn rootworm, which is unimportant when corn is grown only once every two or more years. Thus, this change has resulted in a need for additional chemical control.

Crop rotations in which forage crops, grains, and row crops or summer fallow occur in sequence are often sufficient to prevent serious infestations of weeds, insects and diseases specific to a particular crop, as well as the important service of preventing soil exhaustion. Rotations are of less value in preventing infestation by wide-ranging pests and air-borne fungus spores. On the other hand, crop rotations are the most practical means of controlling some nematode pests, such as the sugar-beet nematode and the golden nematode. The trend toward increasing use of forage

crops in long rotations, as indicated by C.F. Bentley[20] and N.R. Richards[21] will not only improve productivity but will also tend to reduce the importance of some insects and other pests and diseases.

Mechanization and improved machinery have greatly improved the ability of growers to carry out control practices at the precise time they are most effective. Factory production of poultry and hogs requires that effective provision be made to avoid the introduction of diseases and parasites and to maintain freedom from them at all times. At the same time, mass production favors econnomies in the application of pest control measures through bulk purchasing and the use of more efficient equipment.

There is, therefore, a continuing need to study the effects of new methods, to discard the methods no longer useful, and to develop appropriate control measures under new conditions.

2. Use of Resistant Varieties.
A variety with high resistance, or immunity to a disease or pest that normally attacks the crop, provides control at no expense to the grower. Even when resistance is not complete, other control methods may be unnecessary. For these reasons, development of varieties resistant to diseases and insect pests, combined with other desirable agronomic characteristics, has become an important objective of modern agriculture. Resistant varieties are especially valuable in crops where the profit margin is small or where chemical controls are impractical or ineffective.

Selection and breeding for resistance to diseases began early in the present century when it was found that resistance of wheat to stripe rust was inherited as a simple recessive character. Since then, introduction of resistant varieties from other regions, selection and plant breeding for resistance have become increasingly important in the battle against plant diseases.

In Canada, development of disease-resistant crop varieties really began with the program initiated in 1925 at Winnipeg to develop cereal varieties with resistance to plant diseases. From this work, and work elsewhere in Canada and in other countries, has come a succession of cereal varieties with resistance to stem, leaf and crown rusts, smuts, and root rots, that have been a major

factor in reducing the hazards of grain production in all parts of Canada. The outstanding introductions are: Lee, Selkirk, and Pembina hard spring wheats, with high resistance to stem rusts and smuts. In oats, Ajax, Rodney, and Garry varieties are highly resistant to rusts. T. Johnson[22] has outlined fully the problems encountered and the accomplishments arising from these.

In contrast with the large number of disease-resistant varieties that have been produced, only a few varieties with high resistance to insects or mites have been developed, perhaps because sources of resistance were not as readily obtained, and because many of the insect pests were controlled by chemicals or other means. However, varieties of corn and sorghum with considerable resistance to the European corn borer, grasshoppers, chinch bugs and the corn-leaf aphid, of winter wheat with practically complete resistance to the Hessian fly, and of alfalfa varieties resistant to the spotted alfalfa aphid have been developed in the United States and have proved of great value against these pests.

In Canada, the most important varieties with resistance to insects are Rescue and Chinook spring wheats. Since they were released most of the losses caused by the wheat stem sawfly in Alberta and Saskatchewan have been eliminated. Other insect-resistant varieties include the Laurier canning pea that has high resistance to the pea aphid and lines of corn resistant to the European corn borer. Sources of resistance to potato aphids, flea beetles, and the Colorado potato beetle are known but have not been incorporated into any of the varieties grown in Canada. Some resistance to the cabbage maggot has been found in rutabaga and cabbage, but this has not yet proved sufficient to eliminate the need for chemical control of this pest. Because more and more insects are becoming resistant to chemicals, more attention is being devoted to developing crop plants with worthwhile resistance to them.

The plant breeding aspects of the development of resistant varieties have been given by J.R. Weir[23] so need not be discussed here. In developing disease-resistant varieties, it soon became evident that more than one race of the pathogen, differing in pathogenicity to its host varieties, occurred. Stem rust of wheat has several hundred races and by hybridization on its alternate

host, barberry, may produce other new races. Means of identifying these races and determining the reaction of crop varieties have been developed by the use of differential hosts. Genetic studies by Flor[24] have indicated that as new resistant hosts are produced, the parasite is likely to respond by producing a race virulent to them. So far, it has been possible to find sources of host resistance to new pathogenic races. But the time may come when all available genetic sources are used up.

In the development of insect-resistant varieties essentially similar principles apply, except that insects are less closely associated with the host plant than is a plant disease organism. Resistance or susceptibility may be due to attraction or repellent qualities, toxic substances or lack of an essential nutrient. Thus, resistance in peas to the pea aphid is associated with low amino acid and possibly high sugar content in the plant sap. In corn, resistance to the European corn borer is due, in part at least, to the presence of a toxic compound, methoxy-2(3) benzoxazoline. Various other toxic or repellent substances have also been reported in plants resistant to insects.[25]

In the next few years considerable progress may be expected in the development of plant varieties with resistance to fungi, diseases and viruses, insects and other pests. At the same time, the associated physiological and biochemical studies should produce a fund of information on life processes that may well provide leads to other improved approaches to control.

3. <u>Biological Control.</u>

(a) <u>Parasites, Predators and Diseases</u>. Biological control, or the purposeful use of parasites and predators and disease organisms for the control of pests, chiefly those of foreign origin that escaped from the natural enemies that kept them in check in their original environment, has had somewhat limited value in the protection of agricultural crops in Canada. Successful control of 7 species out of attempts against 20 crop pests has been obtained through the introduction of parasites and predators. Chemical or other means of control of the pest are still necessary in all other cases, even in the few where partial control was obtained. From experience and research[26] it appears that the introduction of parasites and predators is useful chiefly against those pests that do not directly damage the ultimate product (that is, the fruit or other edible

part) and where the agent has a high ability to find the specific host or prey and is brought from a plant and ecological environment similar to that of the new environment in which it is released. To this might be added that it should not be adversely affected by chemical control or other agricultural practices. The role of parasites and predators, whether introduced or naturally occurring, in the control of crop pests is likely to be secondary to that of other measures until research produces chemicals that are innocuous to them and means of maintaining them in agricultural habitats are devised. The degree to which these objectives are attained will determine the future status of natural enemies in crop protection.

Epizootics caused by bacteria, fungi, or viruses are well known among insects but attempts to culture the pathogens and to spread them among susceptible pests have usually failed to cause appreciable mortality, presumably because conditions were not favorable for infection to occur. However, recently, practical control of pests has been obtained[27] with a few organisms, e.g., Bacillus popilliae Dutky against the Japanese beetle, a polyhedral virus against the alfalfa caterpillar, other viruses against forest insects, and spores of Bacillus thuringiensis Berliner against tobacco hornworms, the imported cabbage worm and other caterpillars. Some of these organisms perpetuate the disease for several generations of the pest without further introductions, but B. thuringiensis acts mainly as an insecticide on the populations present at the time of application. It is as effective against susceptible insects as the best chemical insecticides. A parasitic nematode, DD 136, with an associated bacterium which is readily cultured and applied in a spray has produced worthwhile mortality of various insects where moisture films are present, but it perishes quickly under dry conditions. These, and naturally occurring parasitic nematodes, may prove useful where a film of moisture is nearly always present as in soil and against aquatic or soil insects. Intensive studies now under way of organisms pathogenic to insects are leading to practical, effective uses against some pests. But much must still be learned about their epidemiology, ecological requirements, mode of infection, the nature of the toxic effects, and how they can be cultured and disseminated so as to insure infection and control of the pest against which they are applied. Because biological pesticides apparently are not harmful to warm-blooded animals or to many parasites and predators, they would be most useful on crops where conventional insecticides produce

objectionable residues and against pests resistant to chemicals. Self-perpetuating disease organisms are most likely to be found useful against soil insects or pests of forage crops or in other relatively permanent habitats.

Although antagonistic action of one fungus on another has been observed in soil and on fruit and seeds, little success has followed attempts to make use of antagonistic fungi or bactoria in the control of pathogenic fungi. Green manuring, by encouraging certain non-pathogenic fungi, reduced infection by the potato scab organism, and somewhat similar effects on other soil-inhabiting disease fungi have been obtained from similar practices. But, for the immediate future, antagonistic microorganisms are unlikely to have an important place in disease control.

(b) Genetic Control. The success of the sterile-male method of controlling insects, by means of which the screwworm was eradicated in Curacao and Florida[28] has focused attention on the possibilities of achieving control of other pests through the application of genetic principles to pest control.[29] In principle, control or eradication of a population is possible through the release for a few generations into a normal population of an overwhelming number of sterilized males who retain normal sexual behaviour and compete on even terms with normal males for the females. Knipling[28] has also shown that even more rapid reduction in numbers would occur with treatment of a population with, say, a chemical that caused sterility of 90 per cent of both sexes, because in this case the sterile males would prevent reproduction by 90 per cent of the females that escaped the sterilizing agent, thus reducing the numbers of the numbers of the succeeding generation by 90 per cent.

In Canada, the possibilities of controlling the codling moth by the sterile-male method are being tested in British Columbia. This work is still in preliminary stages but the results are encouraging and suggest that at a radiation dosage slightly less than that needed for 100 per cent sterility, the progeny of irradiated males and normal females were mostly sterile males, thus carrying the effect into the second generation.

The sterile-male method has still to be proved useful with other insects than the screwworm. Similarly, though certain chemical sterilants have shown promise in American studies, practical uses have yet to be developed. Chemical sterilants have

greater potential usefulness than the radiation method provided they can be readily administered to natural populations in baits or sprays without hazard to man or domestic animals.

Other approaches to control by genetical methods are theoretically possible. One is to use a race of a closely related species that interbreeds with the population in the area of introduction and produces sterile intersexes, as occurs when the Japanese race of the gypsy moth is bred in the laboratory to the race present in North America. Still other possibilities include the introduction of strains of males carrying dominant genes for an abnormally high sex-ratio of males to females such as occurs in a strain of an *Aedes* mosquito,[30] or of strains with genes for other characters that cause reduced survival or fecundity by interfering with this pause or synchronization of life stages with food supply or seasons.

Genetic methods for the control of animal populations have exciting possibilities. Their development, however, requires team work of the highest order with participation of geneticists, physiologists, biochemists, other specialists, and general biologists.

4. Chemical Control.

The steadily-growing importance of pesticides in plant and animal protection is indicated by the wholesale value of pesticides sold in 1950 and 1960. In the former year, agricultural pesticide sales amounted to $7,200,284 and in 1960 they amounted to $20,156,284. Sales of insecticides and fungicides more than doubled, pesticides and biologicals for livestock tripled, and herbicide sales increased by one-half.[31] Herbicides were used in 1960 on more than 22 million acres in Western Canada, where nearly all the herbicide is used. The bulk of insecticides and fungicides are used on fruits and vegetables and as seed dressings for cereals and vegetables. Other uses fluctuate, depending chiefly on the extent and severity of grasshopper and cutworm outbreaks. An analysis of pesticide usage in Canada in 1954 by A.W.A. Brown[32] may be consulted, with the reservation that chemicals change and herbicide usage has increased greatly.

Since the late 1940's the potent synthetic organic pesticides have almost completely supplanted the earlier, mainly inorganic, chemicals. The modern pesticides have extended the use of chemicals for crop protection because they provide outstanding effective

control of pests, diseases and weeds at low dosages. They are available in a variety of formulations designed for nearly every condition of use.

The development of systemic insecticides for the treatment of animals and plants to free them from pests is one of the most recent and outstanding accomplishments in chemical control. Such uses are as yet limited chiefly to the control of cattle grubs and lice and to aphids and mites on plants.

Insecticides and insecticide-fungicide seed dressings at a cost of a few cents an acre have provided the first practical chemical control of wireworms in western grain fields. Seed dressings and furrow or band treatments now provide protection for many vegatable crops against various soil insects and some plant pathogens.

Sprays have largely replaced dusts because they provide more uniform and persistent deposits and they create less hazard from pesticide drift. The development of low-volume sprayers and spray nozzles that apply five gallons of spray per acre made herbicide and insecticide application to large areas practicable.

A few other important developments in application methods follow. Automatic hydraulic and air-blast concentrate sprayers have removed much of the drudgery and unpleasantness from orchard spraying and enable one operator to treat areas in a few hours. High clearance sprayers or dusters and aircraft respectively have extended chemical applications to tall row crops and to tall maturing crops where ground equipment is not practicable. Granular applicators are the most recently designed equipment for pesticide application to soil.

Since the herbicide 2,4-D was introduced many other more selective herbicides have been developed with selective effects on weeds in most crops, without injury to the crop. Even wild oats can be controlled in barley, wheat and flax, though not yet in oats, selective by herbicides that are commercially available. As about 70 per cent of the crop acreage in Canada is severely infested by this weed, the effect in increased crop production will amount to many millions of dollars annually. Other herbicides, such as simazine and atrazine, are soil treatments which do not affect corn but provide complete weed control for the whole season with-

out tillage.

Many insecticides are toxic to man and domestic animals as well as insects, whereas a few are toxic to insects but not to warm-blooded animals. This led to systematic biochemical and physiological studies of the fate of these chemicals in insects and in warm-blooded animals to reveal the chemical reactions and enzyme systems involved. From such studies the mechanism of degradation malathion in mammal and potentiation in the insect was determined, and provided the basis for rational development of other insecticides toxic to insects but not to man.[33] Similarly, the differential and specific toxicity of herbicides and fungicides to crops and various fungi and weeds provide a basis for developing economic uses.

Although pesticides now available provide excellent control of many of the pests affecting agricultural crops, much remains to be done to improve their usefulness and effectiveness. These include improvement of formulations, determination of immediate and residual toxicity to pests, pathogens and weeds, determination of the influence of various physical and biotic factors on performance, and residues on crops.

Although some agricultural uses of pesticides are potentially hazardous to wildlife, such uses have apparently had few serious effects in Canada. This aspect has received limited attention. Joint research by wildlife and pest-control specialists should be expanded and strengthened to place agricultural uses of pesticides on a rational basis to ensure adequate crop protection, while also providing protection for desirable wildlife. See "Pesticides and Wildlife in Canada", by C.A. Cottam, Resources for Tomorrow, Vol 2, pp. 919-930, for details about the problems involved.

The effect of pesticide uses on soil fertility is another problem. Accumulation in soil from repeated heavy applications of persistent chemicals, such as arsenicals, has in a few instances resulted in reductions in yield of crops. Such effects have rarely been important in Canada. However, toward the end of the era of arsenical sprays, a few instances of toxicity to plants were observed in orchards that had been sprayed heavily for a great many years. The change to modern synthetic organic compounds eliminated the hazard from arsenic and some other inorganic

pesticides. Further research indicates that accumulation of toxic amounts in soil of the newer chemicals is not likely to be sufficient to affect crops or beneficial soil micro-organisms adversely, because in most cases they are degraded more rapidly than they accumulate. Continuing and expanded research on the performance, persistence, and degradation of pesticides in soil is essential to produce the knowledge needed for the development of pest control uses that have no harmful effects on soil, beneficial soil organisms and crops, under the varied soil, crop and climatic conditions in Canada.

Still another problem is that of toxic residues on foods resulting from chemical control. To ensure that these uses are not dangerous to man or animals, the toxicity of pesticides to warm-blooded animals, and the residues on food under various conditions of use and dosages, are determined by detailed studies. Only those uses which create no hazard to the health of man or animals are recommended. Information will continue to be obtained for every new pesticide and use before it is recommended, and also, checks are made by the Department of National Health and Welfare to ensure that the established legal or safe residue levels in food offered for sale are not exceeded.

Resistance to Pesticides.

Perhaps the most important problem in pest control today is the development, by one insect species after another, of strains resistant to one or more pesticides to which they were formerly highly susceptible. Twelve species of insects and mites in Canada and 137 throughout the world had become resistant to one or more insecticides by 1960, and indications are that many other species of insects and mites will soon become resistant to many, if not all, insecticides that initially gave good control. Some species, e.g., grasshoppers, have not yet developed resistance to any insecticide used against them. Resistance is physiological and under the control of single or multiple genes. It becomes stable within a few generations after first exposure by elimination of the individuals with genes for susceptibility. Resistance to one chemical may result in resistance appearing more quickly to related chemicals. Various theories have been suggested for the mechanism of resistance, but biochemical and physiological studies[33] indicate that resistance is usually conferred by a specific enzyne present in resistant but not in susceptible individuals which degrades or otherwise inactivates the insecticide before it can kill.

Resistance to antibiotics and other chemicals has been developed by parasites and animal disease bacteria to the point where the problem is similar to the complex problems in medicine. In contrast, no evidence has been reported for the development in the field of resistance to herbicides by any weeds, nor of resistance to fungicides by any of the plant pathogenic fungi, even after such chemicals have been used for many years. Therefore, resistance to herbicides and fungicides seems unlikely to become a problem in the near future.

Means of overcoming or preventing resistance to pesticides is a pressing problem since we are running out of effective materials for some pests. Attempts to counteract the detoxifying mechanism with synergists or inhibitors have met with some success and may eventually provide a solution to this phenomenon. However, insects may have genes for resistance to these materials. Rotating insecticides with different toxic properties is another possible method, although this may bring about resistance to all compounds more quickly than where one is used until it fails before another is used. An insecticide that is more toxic to a strain resistant to another insecticide than to its susceptible strain offers a more lasting solution, since by alternating or simultaneous use of such chemicals, no individuals resistant to both insecticides would appear.[34] Insecticides negatively correlated for resistance have been reported, but their value is still in question. Various other methods of approach involve the selection of chemicals, timing and dosage of formulation, the development and use of biological agents and resistant varieties, and the restriction of use of chemicals to those which permit natural enemies to survive.

<u>Control of Livestock and Poultry Diseases</u>.
Efficient production of livestock and poultry requires the maintenance of disease and pest-free animals. Such practices have been developed for most of the pests and many of the important diseases through studies of the disease agents, their epidemiology, and of sanitary, biological and management practices for their control. The control of highly contagious livestock and poultry diseases has been achieved mainly through exclusion of the disease (e.g.,foot and mouth disease)from the country by prohibiting importation of animals from infested areas and by strict quarantines, or by isolation of herds or flocks that have become

infected, and the slaughter and destruction of such animals and contact animals, disinfection of affected premises, and appropriate sanitary and production practices that prevent or minimize spread of infection both within and between herds and flocks. Destruction of disease carriers and immunization of other livestock and poultry are adequate for some diseases. For still others, such as common respiratory disease in poultry, isolation, management and sanitation measures are the main means of control, as effective antisera or vaccines are still to be developed. For internal parasites the principal means of control are chemo-therapy, rotational grazing, and other management practices. In developing these measures, detailed knowledge of the parasite, its requirements and life history in and outside the host are essential, and, in addition, chemical therapeutants must be effective against the parasite or disease organism, yet have minimal effects on the host. The margin is often small, and, further, the uses must be such that residues do not appear in milk or meat products.

Mass production of poultry and hogs, and feed-lot finishing of cattle has increased the importance of maintaining flocks or herds free from diseases and pests; at the same time the effectiveness of controls is enhanced because of better management and provision for isolation, treatment, sanitation and vaccination or chemo-therapy to prevent or control infections. However, if any of these practices is faulty, diseases may spread quickly with more disastrous effects on productivity than if the animals are distributed in several small establishments. Therefore, it is especially important to maintain strictly the necessary control practices in large production units.

Although excellent control of several important diseases has been achieved, further improvements in diagnosis, detection, and control may be expected from research under way. This will be the result of increasingly fundamental studies made possible by advances in knowledge of diagnostic features and epidemology of disease organisms, life processes of parasites and host, immunology and in the development of improved vaccines and serological tests. Such advances are especially required for diseases not now adequately prevented or controlled(e.g., common respiratory diseases of poultry) and of various other virus, bacterial and protozoan diseases of the alimentary, respiratory, nervous and genital systems. These include many difficult problems. Control of insects and ticks that infest domestic animals or birds are now reasonably satisfactory, but much

still needs to be done if mosquitoes, horseflies and black flies, which are serious pests, especially in fringe areas of settlement where breeding areas are too extensive for adequate control by drainage or chemical means, are to be controlled. Also, repellents of greater effectiveness and persistence than those available are highly desirable. Further, as some animal diseases and parasites also affect man, the elimination of such diseases, as has been done with tuberculosis in livestock, is essential for adequate prevention of their occurrence in man.

Integrated Control.
Integration of pest control measures in a comprehensive production program that also provides for pest control and for cultural, nutritional, and economic aspects of production is a development well under way for some crops, and one that may be expected to become a general practice. Steps in this direction have been taken in California, Arkansas and Arizona,[35] where an entomologist hired to supervise pest control in cotton and alfalfa determines the course of infestations and selects and supervises the control to obtain the best results. To a degree this is now practised in Canada in the production of fruits, some vegetables, and special crops, in that chemical control of insects and diseases, fertilization, pruning, thinning of fruit, and weed control schedules and practices are planned in advance. Similar programs are also developing in the large-scale poultry and livestock production units, and in some instances the operations are determined and supervised by a consultant or specialist, or they are based on timely advice provided by extension services. There has been less tendency for such overall planning by general farmers. Supervised control integrated with other necessary production practices promises to be the next major advance in pest control with all operations supervised or controlled by a consultant or other specialist.

Chemicals are essential to modern crop protection, where little or no damage to the product can be tolerated. But their indiscriminate use creates serious problems of resistance, and leaves toxic residues on food and forage crops. There is the secondary effect of the resurgence of pest populations and the rise to pest status of species normally unimportant due to the destruction of their natural enemies.

The pioneering work by Pickett[36] in Nova Scotia apple

orchards has shown that chemicals and natural control agents can be utilized to avoid most of these problems while reducing the number of chemical treatments and costs to about $4.50 per acre for chemicals as compared with $50 per acre under similar conditions in New York where conventional spray programs are used. In Nova Scotia, only those chemicals and rates of application (e.g. ryania and lead arsenate for codling moth, glyodin for apple scab) that are relatively innocuous to natural enemies are now used. With this program natural enemies have prevented economic infestations of mites, the oyster shell scale, and other insects and have helped to reduce the abundance of the codling moth to low levels. Somewhat similar results have been obtained in Quebec from spray programs favoring survival of natural enemies.

Elsewhere in Canada, less success has been achieved in reducing pesticide usage in orchards and increasing the effectiveness of biological control because the widely effective insecticides required to control the oriental fruit moth and the codling moth also kill natural enemies. Reliance has to be placed almost entirely on chemicals for adequate control of all pests.

Long-term "life-table" type population studies to evaluate the mortality factors affecting pests are being made to discover principles governing the effects of weather, biological agents, and cultural and chemical control. From these, mathematical models[37] expressing abundance as a function of the previous years' numbers and of all the measurable mortality factors can be formulated. Important regulating factors can then be determined and proper combinations of biological, cultural and chemical factors that will result in non-economic numbers can be selected.

Conclusion

The many aspects of disease and pest control in Canada have only been indicated. Details must be sought elsewhere. Remarkable progress has been made in recent years in the solution of many pest and disease problems. Yet many of these problems require better, more effective and more practical solutions, because present methods are not fully satisfactory and some have created serious new problems in solving an old one. Advances in knowledge that are continually being made will increase effectiveness of many present controls. New approaches arising from basic studies in physiology, biochemistry, genetics, and ecology promise even more adequate and

more permanent solutions. To capitalize on the available knowledge, adequate provision for disseminating information and securing its adoption in practice is essential. This is the key to the adequate protection of all crops from damage by its pests and diseases.

Future Research Needs

Because of the great variety of problems in the field of plant and animal protection, the requirements for research on these problems are correspondingly diverse. The easy problems have largely been solved; the simple empirical testing that served well in the past is no longer adequate to solve the complex problems that are now recognized. Basic physiological, biochemical, and ecological investigations will be increasingly necessary to provide knowledge and understanding of biological processes and interrelationships between organisms. They will not lead to immediate application in control, but they will provide a base for more lasting solutions. Although new knowledge will affect the course of research, the following are perhaps the more important lines of investigation in the near future:

1. Development of chemical means of overcoming the development of resistance to pesticides by insects, mites, and bacteria. Of all problems in pest control a solution for the resistance problem is most urgently needed. Many approaches to this are possible and include: the search for, development and evaluation of pesticides effective against pests that have become resistant to conventional pesticides; determining the value of rotation or alternate use of pesticides with different modes of action; studies of modifications of methods and timing of application, formulation, etc., to achieve control without the development of resistance by the pest or with at least delay in the onset of resistance.

2. Continued development of chemicals, especially those with high selectivity against given pests but which are non-toxic to warm-blooded animals and crop plants, or which under the required conditions of use leave no residues harmful to livestock or man. This includes development of principles of pesticide usage to provide a solid basis of knowledge about persistence or degradation on, or in the plant or animal to be protected, and the effect of soil, weather, physical and biotic factors, formulation, dosage, placement and distribution of the deposit on performance against pests

and pathogens; determination of the effects of chemical treatments on natural enemies of pests, wildlife, soil and crops to find those that provide satisfactory pest control yet do not affect natural enemies, soil fertility, or crop growth adversely.

3. Continuing and increased effort to develop crop varieties resistant to pests and diseases. This is now a major objective in the control of plant diseases, but has not been as widely used for the control of insects and related pests. Consideration may have to be given to the development of crop varieties with increased tolerance of herbicides and possibly other pesticides.

4. Increasing attention to studies of the life-processes of pest and disease organisms and their hosts to clarify host-parasite interrelations, and especially to assist in developing new pesticides and resistant varieties of crops. Although much information has been accumulated for some species, this is only a beginning.

5. Studies of nematodes and viruses, their biology, host relationships and control, at all levels from background to fundamental, because of their steadily increasing importance as plant and animal pests.

6. Study of the possibilities of genetic methods of controlling insects and other pests. This involves a search for sexual sterilants, whether physical or chemical, and ways of using them. Another approach is to find strains of pests with inherited harmful characteristics that can be introduced into natural populations so as to put natural selection into reverse so far as pests are concerned.

7. Long-term ecological or population dynamics studies on diseases or pests to obtain basic information on the factors governing abundance and to evaluate the role of control practices, especially the use of chemicals, with the object of developing an integrated program of production that utilizes natural factors, production practices, biotic agents, and chemicals, to the best advantage in the protection of crops and animals from all their pests and diseases.

8. Studies to develop systemic fungicides or antibiotics that provide adequate protection throughout the period the crop is susceptible to infection. Studies already under way on systemics for the protection of domestic plants and animals against insects and nematodes should be expanded, since they may offer simpler and more econom-

cal control where protection is needed over a long period of time.

9. Studies of bacterial, fungus, and virus diseases of pests and of parasites and predators, and development of practical means of utilizing these in the control of crop and livestock pests.

10. Determining the possibilities of eradicating newly-introduced pests and some pests or diseases established in a limited area. Eradication measures have been used successfully to eliminate malaria in the subtropics and tropics, the Mediterranean fruit fly and the screw-worm in Florida, and other pests and diseases in the United States. In Canada quarantines and eradication measures have prevented foot and mouth disease, hog cholera, and several other diseases from becoming established and endemic. The success in these cases indicates that more could be done to eradicate pests and diseases before they become widely distributed.

11. Development of reliable quantitative knowledge of the relationships between pest or disease occurrence and abundance, and weather or other environmental conditions, and of these on the amount of damage caused by the organism. This is needed to evaluate more accurately the need for control practices and when they should be applied.

12. Studies in co-operation with meteorologists to develop more reliable forecasts of outbreaks of many species of insects and diseases.

13. Development of methods that ensure that the results from research on crop protection are brought into use quickly and effectively. Although progressive farmers put some measures into practice before they have been adequately tested, many producers do not use them until long after their value has been proved. Frequently, also, the measures are not used in such a way as to obtain full protection because the grower is not fully aware of the problems involved and does not follow recommendations. Too often crop protection is neglected in planning because the nature of the problems is not realized by the operator and nothing is done until considerable damage has occurred. This will probably require many more advisory or extension personnel, and eventually professional consultants or managers to evaluate pest problems on farms and to select and supervise the application of control practices.

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RESEARCH FOR AGRICULTURAL ADJUSTMENT

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The title "Research for Agricultural Adjustment" assumes many things in those four words. It takes for granted that we can define agricultural adjustment and that we can arrive at this state with the help of research. We must agree with both of these assumptions, if the subject is to be discussed profitably.

Let us first attempt to define "agricultural adjustment". This inevitably puts us in a position where we must specify not only ends but also means. The end, we will all agree, is an acceptable standard of living for the farmer, arrived at through adjustments in the factors of production and marketing. One definition of agricultural adjustment which is put forward for the purposes of this conference is as follows:-

> Agricultural adjustment involves the wise and efficient use of our agricultural land according to its particular capabilities, so that farms organized with an optimum relationship between land, labor and capital, efficiently producing products desired by the market, will give farmers an acceptable standard of living.

Such a definition is useful only if we can arrive at answers to the questions it asks--what does "wise and efficient" mean; how do we define "capabilities"; what is the "optimum relationship between land, labor and capital"; what is implied by "<u>efficiently</u> producing"; what do we mean by "desired by the markets"; and lastly, what is an "acceptable standard of living"?

At the risk of leaving the way open for criticism regarding a serious misuse of the term "research", it would appear appropriate to say that the task of research is to <u>assist</u> in

providing answers to the questions implied in the definition, and to assist in providing means by which the various goals can be achieved. It is important to note that the functions of research in this matter are to assist. Research itself will not provide the answers, it can only provide the basic information on which person or persons can say--"If we agree that we want to arrange matters thus and so, then according to the information research has provided, we can achieve that goal by proceeding as follows". Scientific research will not define goals, since these are based on subjective moral and social values, which differ between individuals and are without absolute standards. If we can make the humanistic decisions necessary, scientific research will help us chart the path to the goals we set.

Let us now turn to the ways in which research should be used to help us arrive at "agricultural adjustment".

Agicultural Land and Its Use

While Canada can be proud of her record in the field of soil classification and survey as a result of the co-operative Federal-Provincial program that has operated for approximately thirty years, we have not in general made the logical extension of soil survey information into the fields of land use that we should have. We can be grateful in the present context, that we have the basic information in our existing soil surveys and the personnel necessary, in the form of soil survey staff, to provide, quickly and economically, the land use information we need for an agricultural development program. Using a combination of:

(a) aerial photo interpretation,
(b) existing soil survey information,
(c) local knowledge of climate and agronomic problems in the minds of the soil survey people,
(d) a minimum of on-the-ground checking,

it would be possible, in relatively short order, to prepare maps for the whole of agricultural Canada indicating: (1) present land use, and (2) land use capability ratings (i.e. recommended land use on the basis of soils and climate).

Maps of present land use are a necessary starting place in planning agricultural development programs. Such maps do not generally exist in Canada except those covering local areas, i.e. on a parish or township basis for local tax purposes, or on a

highly generalized provincial or national basis. Maps should be prepared at a scale of perhaps 6 miles to the inch, large enough to be useful as a source of information for regional and local purposes, but small enough so that minor items of unimportant detail are not depicted. Where the information is not available through local tax offices or where census information is too generalized, it can be readily compiled from recent aerial photographs.

Maps of land use capabilities, indicating the classification (suitability and hazards) for different land use purposes, can be readily prepared on a similar scale to that suggested above, utilizing the information at present available on soil survey maps, and that extractable from the interpretation of aerial photographs and the minds of the soil surveyors, plus some minor additional checking in the field where additional information may be necessary. Such information is badly needed today to assist in deciding (a) what present agricultural land is non-agricultural and should be re-forested, (b) what cultivated land should be classified as non-arable and regrassed, and (c) which of our agricultural lands are so valuable as to merit protection from the threat of industry, suburban sprawls, airports, and highways.

Such land classification work should, in the first instance, provide for a minimum number of categories as follows:

- Class I - our best agricultural land including that meriting protection from the threat of other uses;
- Class II - other agricultural land suitable for arable agriculture;
- Class III- land suited for grazing and fodder production, but not suited to arable agriculture;
- Class IV - non-agricultural land, better adapted to forestry or other non-agricultural use.

As a second and later step, more elaborate separations within the Classes I and II may be made, when required for the development programs that may be undertaken. Initially, however, our major requirement is to know the areas of non-agricultural land at present in farms, and the areas of non-arable soils being cultivated; and to identify these on suitable maps for the

guidance of those who will be concerned with the direction and execution of the agricultural readjustment so badly needed. The urgent land use questions are those associated with the misuse of non-agricultural and non-arable lands. The information necessary to identify these is at hand and can readily be compiled, if we do not complicate the study in the initial stages with questions of alternative agricultural use in the areas of the better soils of Classes I and II. These latter questions can be dealt with when necessary and desirable, but at a later stage.

Farm Organization and Management

Even when our present (and potential) agricultural land has been identified, we still need a tremendous amount of information from the farm management specialists as to what kind of farm unit will be necessary to farm the land successfully and what enterprises and crops it is adapted to.

In the initial stages of agricultural readjustment, we need to know much more about the minimum and optimum sizes of grazing enterprise for sheep, beef and dairy cattle in the various parts of the country for those lands that are non-arable, but should remain in or revert to permanent hay or pasture. We also need information on the desirable sizes of woodlot operations on those non-agricultural lands, where a combination of agriculture and forestry could be practiced. In order that we may assist with agricultural readjustment on our poorer lands now, and our better lands in the future, it is desirable that vigorous and extensive research programs in the field of farm management be launched as soon as practicable so that we have some guidance with respect to the size of unit involved, expressed in terms of (a) acres for land of the various classes; (b) dollars for the equipment, buildings, livestock and operating capital necessary, and (c) manpower and work units for the labor involved.

Canada not only has too many farmers on non-agricultural and non-arable land, but also has too many farmers on the arable land as well, operating excessively small units in terms of land and capital. Agricultural readjustment must be concerned not only with the land that is being misused, but also with the land (and the farmers) involved in inefficiently organized farm units.

Canada has, through its various provincial agricultural extension services, a potent means of assisting agricultural

adjustment. Unfortunately, the agricultural representatives and agronomes have been handicapped in their work by two grave deficiencies - (1) a general lack of sufficient fundamental information on which to base a vigorous farm management policy, and (2) the lack of means by which to assist the farmer reach the desired goals.

To take the question of information first, the present farm management studies in most provinces are fragmentary and tentative; even where there are extensive records, these have generally not been analysed and summarized to permit the extraction of guiding generalities. The nature of farm enterprises and the relative emphasis on each differ significantly between the different parts of Canada, governed by differences in climate, soils and markets. Much more comprehensive information is necessary if we are to do sound farm planning and farm management work. We must know the probable return to the farmer of increased inputs of land, labor and/or capital on various farm enterprises under the various environmental conditions existing across Canada. Analysis of farms records available through farm management clubs provides one valuable source of such information, but its usefulness is limited by the relatively minor amount of data supplied from such sources. Much more support by government as well as farmers for the professional manpower needed for these farm management clubs is obviously necessary, and equally essential is the support for the study, analysis and interpretation of the data already available as well as that to be collected. Since we cannot wait ten years for the collection of data, we must base our future farm advisory programs on farm management information extracted from the present data, filling in the gaps by extrapolation where existing information is unsatisfactory but, nevertheless, not delaying action because of the deficiencies existing. More data and more analyses will provide better information for the future, but we dare not let "the perfect be the enemy of the good". The information that can be obtained by analysis and extrapolation of existing data will be most useful to the agricultural representatives since their major lack at present is farm management information. Their job is no longer primarily one of passing technical information with regard to details of the operation of individual farm enterprises, e.g. disease control, fertilizer usage, recommendations on varieties, etc., but rather one of making recommendations regarding the integration and relative emphasis on the various farm

enterprises possible and adapted to the area. Much more information must be put into the hands of the agricultural representatives and agronomes by analysing and interpreting data presently available, and by making sure that we have, as soon as possible, many more of the basic farm records necessary. Without this information, we cannot provide sound advice which will give adequate net farm incomes with the lowest possible unit costs of production.

Provision of Capital

Canadian farms and farmers suffer badly from difficulties existing in the path of change and expansion. We have been forced to change from the small subsistence (or semi-subsistence) farm powered by horses that was characteristic of the period before the agricultural revolution, prior to the time when petroleum power and the internal combustion engine multiplied man's productive capacity by increasing the power each worker could command and, therefore, the amount of productive work he could do. The change to the larger commercial farm, supplying the farm family with an income comparable to that of their wage-earning city cousins of comparable skills and ability has been excessivily slow in coming about; much slower for instance than in the United States. The difficulty may be traced very directly to inherited difficulties with agricultural credit. Canadian agriculture was built with the financial assistance of mortgage credit extended through mortgage and investment companies. In the thirties, with the crop failures coinciding with the depression, some provinces took the drastic, but necessary, step of protecting their farmers from foreclosure by moratoria, by compulsory scaling down of accumulated interest and where necessary by encouraging arrangements for scaling down the unpaid principal. Compulsory renegotiation of mortgages, and interference with normal foreclosure had the obvious effect--commercial sources of mortgage credit in agriculture were no longer available.

It is probable that the total of Canadian farm mortgages held by loan, trust and insurance companies is less than $40,000,000--a negligible amount in relation to an industry which has a total capital value for land, equipment and livestock of about $11 billion. New business would amount to only about $5 million per year. Commercial farm mortgage credit dried up after the depression, and in view of the reasons, it is unrealistic to think that it will be re-established. No effective substitute has been generally

available. The former Canadian Farm Loan Board earned the reputation, perhaps unjustly, of being so conservative that it only extended mortgages to farmers who didn't need them. Provincial sources of farm loans have until recently been limited to excessively small amounts and to excessively short periods for repayment. In any case, most of the existing government farm loan services move so slowly and are so ponderous that the applicant is discouraged from applying.

Vertical integration is a direct result of a shortage of credit since vertical integration permits the farmer to use his own labor, land and buildings, but someone else's money for feed and livestock. The continued concern with the inroads of vertical integration and the loss of control by the farmer represent a reflection of a situation that need not have grown to the extent it has, if adequate credit - both short - and long-term - had been available to permit farmers to expand and change, and at the same time to control their own farms.

The ultra-conservative nature of the Bank Act in Canada has preserved a sound banking system, but its barriers against dealing in farm mortgages, and the traditional reluctance of the chartered banks to engage in agricultural credit, have not operated in the interests of easy agricultural readjustment. The changes in policy of some of the chartered banks in looking for farm loans is most encouraging, but it must be noted that the major part of these changes came when government guarantees of such loans were ensured. (QUERY--What part of the interest charged on these loans can justifiably be attributed to risk?).

Nevertheless, Canadian agriculture badly needs additional sources of long-term mortgage credit, and in generous amounts. A farm which will give a family an income equivalent to $5,000-$6,000 in the city (not a large return for the labor and managerial skills required of a farmer) represents a capital investment of not less than about $40,000-$50,000 today. Unfortunately, most Canadian farms are about half this size, a good reason why less than 15 per cent of Canadian farmers pay income tax: Agricultural readjustment will require an enlargement of the physical and capital size of about half of Canada's farms. Where will the money come from for this expansion to permit the orderly absorption by the more successful farmer of the assets of his less successful

neighbour? Today, it is arranged with difficulty (if at all) on the basis of a private mortgage, but this solution is too limited. By failing to put enough cash into the hands of the man selling out, it actually delays transfers that would go on rapidly with more plentiful mortgage credit. The distressing symptom of hundred-acre farms, too good to be allowed to go back to forest and representing too much sacrifice by our pioneer forefathers not to be kept in at least extensive agriculture, going begging for asking prices of less than $3,000 in parts of Eastern Canada, is a direct result of a shortage of mortgage credit.

Canada badly needs an agricultural development bank. Such a statement may come as a shock to those, particularly in government circles, who think of these as symptoms of the underdeveloped countries. Canada needs an agricultural development bank in order to guarantee farm mortgages with commercial investment firms or, alternatively, to grant such mortgages itself, but without the delays due to excessive centralization, characteristic of present government lending agencies.

Such an agricultural development bank needs farm management specialists as inspectors and advisors, in exactly the way that the V.L.A. administration uses its field staff. The provincial extension services now have fairly extensive and well-trained staffs of agricultural representatives--men who are badly handicapped in their work by a lack of means by which to assist the farmer to reach agreed goals, as mentioned above. Agricultural credit is much more effective when made available as supervised credit, with supervision of both the proposals for the use of credit, and of the execution of the plan throughout the period of the loan. Similarly, agricultural extension work could be much more effective if the extension man was able to say not only "This is what you should do" but also "and this is how you can do it".

The addition of credit supervision to the duties of the district agriculturist would make him a very effective partner with the farmer in agricultural readjustment.

Serious study should be given to the operation of existing arrangements for the provision of long-term farm mortgage credit, both in Canada under the V.L.A. and other more recent provincial arrangements, and in other countries where agricultural development

banks and supervised credit have operated, in order to arrive at the most satisfactory answer for Canadian conditions, which are not those of other countries.

As a separate part of such a program, an intensive study should be made to find ways and means of making our agricultural extension workers most effective in agricultural readjustment. In addition to studies of the comparative effectiveness of various extension methods and techniques in publicizing technical information, comparisons should be made of situations where the agricultural advisor is part of a supervised credit program (or, where credit is readily available) with situations where agricultural credit is difficult and the agricultural extension man is not able to help in finding additional financial resources.

Canadian agriculture is remarkable for the fact that it is the only major Canadian industry that functions without significant commercial credit, and in addition it is the only example of an agricultural industry that has neither commercial mortgage credit nor an agricultural development bank. Such limitations to change and expansion restrict the rate of agricultural readjustment. The impact of these limitations deserves study and attention, in order to devise solutions that will remove the difficulty. Without adequate long-term credit, desirable changes will come about at a painfully slow pace. With adequate long-term mortgage credit (secured by the land alone), the normal competition between the more efficient and the less efficient will accelerate the rate of agricultural evolution and speed the day when the majority of our farmers are enjoying a reasonable standard of living, and producing, at minimum cost per unit, the products the market needs.

<u>Labor Saving Machinery</u>

The day has passed when we could feel that we had adequate farm labor supplies in Canada. The attractions for the wage-earner of higher salaries in industry together with the improved standard of living that he obtains in the city, has meant a rapid decrease in hired labor on the farm. This drift will maintain itself since few farmers can compete with industrial wages.

The remedy for the shortage of labor and the high cost of hired labor has been applied through farm machinery. However, it is recognized that much more developmental work needs to be

done to devise sizes and types of machines which are adapted to the specialized family-size farm, where the labor force consists of the farmer and his family. The development and popularization of inexpensive farm machinery, operated where necessary by the power take-off from the tractor and arranged for fast, easy coupling and uncoupling so as to permit the man and his tractor to do a number of different tasks in one day, e.g. forage cutting, hauling and silo filling, is badly needed. An arrangement which permits this kind of job to be done easily and efficiently is a prime requisite for efficient production. The complex requirements for farm machinery will inevitably force farmers into specialized enterprises in order to avoid the capital costs to mechanize a large number of small enterprises.

When we can achieve the size of farm enterprise that a man and his family can handle adequately by being well-equipped with the farm machinery necessary to make the best use of his labor, then we can take pride in feeling that we have made the correct balance of land, labor and capital desirable for an efficient production unit.

With the provision of adequate supervised long-term credit, we should be able to arrange that the 250,000 farmers of tomorrow have as much land as they can manage efficiently; and with correctly designed farm implements, their labor will be used to maximum efficiency.

Too little attention has been paid to research in this phase of agricultural engineering, with too few competent engineers and inadequate financial support available for work on the development of farm machinery. It is true that industry carries on a fair program of development and testing but, until recently, most innovations have been the result of "necessity being the mother of invention" on the farm. Inventive farmers have done an impressive job, but they need much more help from well-trained engineers in the field of farm machinery development than they have been getting.

Marketing Research

It is vital that Canada's farmers produce what the market desires; otherwise, with today's efficient transportation, the market will be supplied from elsewhere.

The market is of course composed of two controlling agencies, the consumer and the distributive and jobbing agencies. The consumer wants quality, convenience and economy, the relative emphasis on these being controlled by income level and a number of other sociological factors, e.g. are both husband and wife working, and therefore prepared to pay more for convenience such as pre-cooking and elaborate processing?

Marketing today bears little relationship to what it was in the past when there was a physical location for the market place where buyer and seller met. Today, with an ever increasing part of our food being marketed by multiple outlet super-markets, the marketing agency that cannot meet the demand for 41 carloads of peaches of a specified quality for delivery next Tuesday, will be left waiting at the church. Jobbers, of course, are not concerned with where a product is produced, as long as they can handle the business, but the producer cannot afford to take the same cavalier attitude--his livelihood is at stake. The producer can no longer be satisfied with saying he is producing a good product and, therefore, the world will beat a path to his door. In food production, the producer must beat his way to the consumer's door and must, in consequence, be concerned with <u>how</u> it is marketed in order to make sure it <u>is</u> marketed. Marketing boards, co-operative marketing, and contracted production are all part of this pattern, and will grow as the number of buyers continues to diminish.

Since the number of wholesale buyers has steadily decreased, the bargaining position of the individual producer has steadily deteriorated. His defence has been to join a group, pooling his production with a number of others and entering the market with the large volume of assured supply that the distributor requires.

The difficulties common to all forms of marketing organization are serious, whether the form be the contract type as in milk, or in the products associated with "vertical integration", or whether it be in co-operative marketing as it used to be in the Wheat Pool, or in marketing boards such as we now see nationally in wheat, and provincially in a number of products. Problems are numerous and grave enough that intensive study and exploration of all the various ways of arriving at desirable marketing arrangements, with the best interests of both the producer and the consumer at heart, is a must if we are going to avoid more difficulties than those we

already have.

Obviously, one aspect that needs more attention is the consumer's wishes. Some products such as meat and milk are marketed under grades and sometimes under price controls that no longer serve the purposes they did. With government controls, grades and marketing change slowly. The voices of both the producer and the consumer are scattered and weak in pressing for changes. More attention needs to be given to what the market really wants, so that this can be defined adequately in terms of changes needed in existing legislation. Support for such studies by both producer and consumer groups, would make sure their voices are louder in pressing for such needed changes.

An Acceptable Standard of Living for Farmers

With Canada having become primarily an industrial nation, two aspects of this industrialization are of more than passing interest to farmers. First, an industrial society is going to provide itself with cheap food, irrespective of where it gets it. Second, with free movement of labor, no segment of the population will, over a long period, put up with low returns for its labor. With respect to the first of these propositions, we can foresee that agricultural adjustment will mean, in the long run, giving the industrial worker the products he wants at the best price he can buy them. The pressure will be for prices competitive with world prices, and our agricultural evolution can only move in this direction. Inefficient production by a large number of overly small producers means high cost production, which either is artificially supported by subsidies (which are temporary, albeit in some cases of long standing) and in the end leads to such farms being replaced by more efficiently organized productive units. The large corporation farm is also a high cost producer--and an inflexible producer, since the economies that are possible on the family farm when the family reduces its demands in times of economic stress, are not so easily arranged. When agricultural prices are good, either through cyclical variation or as a result of successful pressure for subsidies from high cost producers, corporation farms will flourish. When prices are low, the corporation farms cannot take in their belts as easily as the family farm and, hence, the stable structure that will produce agricultural products more efficiently will eventually be the family farm. With adequate sources of credit, neither the small producer nor the corporation farm will seriously threaten the major place of

the large but efficient family farm, with little or no hired labor, for the future. Economic forces should move inexorably in this direction.

With respect to the second proposition, we can expect that agriculture will evolve so as to reduce the present disparity whereby returns to farmers are less than for most other comparable occupations involving the use of managerial skills, labor and capital. Even if the parents are content, the children will not continue the tradition. The relatively low returns for labor and capital in agriculture imply that pressures for change are operating. At present, there is unanimous agreement among those concerned with the welfare of agriculture that the average farm business is too small to use the farmer's labor (and his equipment) efficiently. Since no major increase in developed land resources is foreseen, we can confidently forecast a further decrease in the number of farmers until we reach a level of about 250,000 commercial farms.

Under these conditions, we would expect that farmers would have a standard of living comparable to that of a skilled tradesman in the city (a master carpenter or a plumber) and, at today's level, we might think of an average return of the order of perhaps $6,000. per year for labor and capital. With the right kind of agricultural readjustment, we could look forward to this and could take real pride and pleasure in the improvement this represented over today's situation.

Little has been said in the foregoing about research for production itself. Today, it is recognized that research is ordinarily about ten years ahead of application on the farm--most farmers are convinced that they know how to farm much better than they can afford. Unfortunately, this would seem to be so. Research must continue to stay ahead of practice, and no reduction in the force and facilities available for research to improve physical production should be considered.

The main deficiencies in our present knowledge for the major adjustments necessary are primarily in the fields of land use, farm management, agricultural credit, aspects of agricultural engineering devoted to efficient machines for the larger one-man specialized family farm, and in marketing research.

We know roughly where we want to go but our route at the present time lacks definition since our basic information is insufficient. However, the deficiencies can easily be made up with adequate attention to the pressing problems by those already in these fields, and by financial encouragement, through the establishment of research positions and the provision of postgraduate assistance, to attract additional workers into those branches of agricultural science where staff shortages exist.

Agricultural readjustment is already going on apace, but our problem is to prevent tragedies and to speed it up where this is necessary. The reversion of good arable land to forest is a tragedy that we should prevent. Similarly, the development of vertical integration on one hand and the agricultural slum on the other, is a symptom that the evolution toward the efficient family farm has been too slow.

Our research needs, though not very large in magnitude, are pressing indeed in terms of time if we are to avoid additional difficulties in an industry seriously beset with onerous problems.

A TYPICAL DRAINAGE BASIN: THE OTTAWA RIVER

G. Prévost,
Chairman,
Quebec Water Purification
Board

Our assignment is to give a picture of the present uses of the Ottawa River and to review the factors that should be studied to secure the best returns in the future. But we cannot study the river without also studying its watershed. Some part of every drop of water falling in the watershed finally reaches the Ottawa River, and what happens to that drop of water in its long journey, its chemical or physical change, will dictate the use we can make of the river. At a certain degree of pollution, water can have no use at all. Life in the region could be doomed. We must therefore endeavor to find the best use of this water, for the benefit of the majority of people now and in the future.

A favorite term nowadays is "multiple use". But there are limits, since an attempt to multiply uses may mean sacrificing some very useful single use. Conversely, an attempt to overdo a single use may jeopardize other uses, present and future. What we really must aim for in any specific field is not maximum but optimum use. We must keep a sound balance among the different uses of the water and a safety margin for future possibilities. With watchfulness as our keynote, and after mature consideration of all the factors involved, we must decide the rational planning of our future resources. That is the long-term aim.

For the time being, however, all we can do in most of the cases is postulate general principles and raise a number of questions which may only be answered by teams of scientists after long and methodical research. Every participant at this conference could with advantage have been invited to co-operate in the presentation of this paper, since every one has a share in it. A difficult task, indeed, has been placed on our shoulders; and our attempt to fulfill it requires your indulgence. We could get to the core of the

subject right away, speaking of the actual use of the land and the water; but we feel that the philosophy of planning will be easier to understand if first we give a description of the area and its history. We do so briefly, and append a bibliography for those who may wish to have more information.

In this bird's eye study we will mainly consider the Quebec side, although we will refer occasionally to the Ontario side.

Description and History of the River and its Watershed

The main source of the Ottawa River is Great Lake Victoria, about 150 miles northwest of Ottawa. From there the river flows 700 miles in a meandering course through Ottawa, enlarges itself in a big lake (Lac des Deux-Montagnes) and encircles the island of Montreal, where it joins the St. Lawrence River. The watershed is about 40,000 square miles on the Quebec side and 17,000 square miles on the Ontario side. These two sides offer some geological contrast. The Quebec part is mostly in the Canadian Shield, characterized as every one knows by rock outcrops, minerals, stony soils, lakes and forests, so that in the beginning, at least, forest products should be the major resource and agriculture minimal. But a great part of the watershed on the Ontario side is in the Saint Lawrence plain, characterized by fine textured, dark grey, gleysolic soils and podzols; here agriculture is the natural, the top use, after forest clearance.

The respective silhouettes of the two watersheds are easily imagined. The Canadian Shield is mostly precambrian; it is hilly on account of the last resurgence of the land, but with glaciation the hilltops have been cut down, the highest being Mt. Tremblant, 3,200 feet above sea level. The average altitude is only 1,000 feet. The Canadian Shield line passes at the upper limit of St.Jerome, Lachute and proceeds to Calumet, where a narrow band goes to Petawawa and down on Ontario side in direction of Lanark. So the rest of the watershed is in the St. Lawrence plain and is known as the Lower Ottawa Valley. Here there is clay, and the land is generally flat; the Champlain Sea covered all the area about 10,000 years ago and, in withdrawing, left loose sediments.

The general elevation is between 100 to 200 feet; the limit is 500 feet. In the Canadian Shield there are thousands of lakes among the numerous hills, found mostly on the Quebec side. But

the Ottawa Valley plain has uniformly few lakes.

The average precipitation is 35 inches, rather evenly spread over the year although generally lower between July and October. From this it follows that the Quebec side is well irrigated; the lakes overflow in cascading rivers and take a great amount of water down to the Ottawa River. But if the Canadian Shield has fair distribution of water all over the land, with good irrigation a different situation exists in the plain, especially on the Ontario side, where there are few rivers and the land is flat. This part is exposed to poor irrigation in the summer and to flooding in the spring or in time of heavy storms.

The air temperature may vary from below zero to over 90° Fahrenheit. Frost may persist 6 months in the Victoria Lake district, but only 4 months in the Montreal area.

The earliest known inhabitants of the wilderness which this basin originally constituted were the Indians, the Algonquins, who probably lived there for many centuries before the arrival of the Europeans at the beginning of the 17th century.

The Ottawa River was first mentioned by Champlain in 1603, and ascended by him in 1613. The first European who ascended it was Etienne Brulé, in 1610. In 1611, Nicholas de Vignon reached Allumettes Islands, an important Indian settlement from 1600 to 1760. More easily travelled than the treacherous St. Lawrence, the Ottawa was used as a route to the Great Lakes. It was continuously used by fur traders, explorers and missionaries up to the beginning of the 19th century.

The first settler was Joseph Mondion, at Chat Falls, in 1776. An American, Philemon Wright, came to Hull in 1800. Later came the United Empire Loyalists and others from the United States, groups from the British Isles, soldiers and French farmers from the Montreal area.

In 1827, a settlement took the name of Bytown, in honor of the colonel commanding the Royal Engineers who built the Rideau canal. It was renamed Ottawa in 1855 in honor of the Outaouais Indians. Queen Victoria chose this city as the capital of United Canada in 1857, a decision which drew many Scottish and Irish settlers to Ontario and to Argenteuil County on the Quebec side.

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The lumber industry and agriculture were the main occupations of the people and the population increased rapidly, from about 150 in 1800 to 100,000 in 1850; now it exceeds 1,300,000. If we count the population of the Montreal area, which lies at the junction of the Ottawa and the St. Lawrence, we find more than 3,000,000 people living on a stretch of land some 150 miles by 30 miles. They constitute more than two-fifths of the population of the province. Thus we can see the importance of the river and of its watershed and why we should protect them, especially when we know that the population forecast for 1990 is in the order of 8,000,000.

The map* shows the distribution of the population, the location of pulp and paper industries (mostly around Hull) and the mines, (mostly in the Abitibi district). Roads are scarce on the Quebec side, although there are many good logging roads for forest exploration. Dams are numerous for power purposes or log transportation. There is a federal park on the Gatineau River and three Quebec provincial parks, La Vérendrye, Mont Tremblant and Kipawa; on the Ontario side there is a provincial park known as Algonquin Park. They are used for recreation, but forest exploitation is permitted, except on the Gatineau. Many territories on the Quebec side are leased to anglers and hunters. There is good agriculture in the Ottawa Valley but little in the Canadian Shield. Navigation is scant. The watershed on the Quebec side has been called the playground of North America.

Thus one can see the impact of population and its activities on the water of the basin and of the Ottawa River itself. With this general picture in mind, let us see a little more precisely what is being done in this area, and what could best be done in the future in the meaning of today's expressive general term, multiple-use.

Multiple Use of Water

What exactly do we mean by multiple use of water? It is customary to include domestic purposes, fish production, recreation and industry. However, we would like to be more specific and consider six different uses, ranging from the non-detrimental (such as quiet contemplation) to the potentially dangerous (such as waste disposal).

We realize that in this materialistic world it may be difficult to convince everyone of the need to spend money to keep water as pure as possible when there is no immediate or obvious prospect

*Map on page 109

of financial gain. We might be labelled idealists, but without idealistic goals there cannot be much improvement. This conference has been called to set up the highest possible standards. Accordingly, we should not restrict ourselves to immediate practical benefits but try to lay down sound conservation principles for the guidance of those promoting any future project. We will therefore examine the following six broad categories of use.

(1) Contemplation
(2) Bathing
(3) Hunting and fishing
(4) Navigation
(5) Water supply
(6) Waste disposal.

1. Contemplation

What can be more beautiful than a clear, sparkling stream, lightly running over cascades and rapids, surrounded by verdant trees, wild flowers, mossy rocks, craggy mountains? Even more so where man has not interfered with nature and altered the habitat! Virgin country has a special appeal to the soul and for the benefit of man we should preserve certain districts in their natural state, as is done in many parts of the world in national parks. Keeping the habitat unaltered does not preclude prevention of disease by removing diseased trees or other preventive or corrective measures.

If alterations have to be made for the sake of other benefits, let us make every effort to preserve aesthetic values.

From a practical point of view, by keeping certain districts unaltered, especially at the source of tributaries, we shall have the added advantage of storing water in the vegetation-covered ground, permitting a steady, regulated flow to lower lands.

To enhance the more beautiful sites, landscape architects, biologists and engineers should work in teams. Trails can then be laid out in the most appropriate manner without affecting the existing biological balance of life. Where motor roads are required, they should be built as narrow as possible, within safe limits. One-way roads appear the most logical to avoid cutting too big a break through forest land. Picnic tables, restrooms and adequate shelters should be provided. Building permits for larger installations,

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such as hotels or restaurants, should always embody specifications laid down by a board of government specialists to ensure that they are in keeping with the general aesthetic level of the region. No foreign matter, no trash, should be allowed to go in the waters. Aside from water damage, floating debris is an eyesore; it may also encourage overgrowth of weeds.

More land for such recreation will be required, especially around the urban areas where, in a few years' time, 80 per cent of Canadians will live.

As an accessory to contemplation, historic sites should be identified and developed, e.g., the site of the Dollard Desormeaux Fort near Carillon. Deep River, near Chalk River, recently yielded the archaeological remains of an Indian outpost of 3,000 years ago. These and other worthwhile features of the watershed should be developed.

Painters, photographers, open-air plays and concerts, artists of all kinds should be encouraged to frequent the appropriate surroundings. Quiet sports, such as hiking and horseback riding should be encouraged. All these activities are enhanced when performed near a lake or a spring of pure water. Here we can see the effect of the water on each activity of our life. Nature study, such as botany, geology, zoology, camera hunting, should be encouraged, as well as skindiving for underwater observation. By the same token we will relieve the pressure on fishing and hunting by directing more people to other activities.

Community leaders should try to develop those activities as much as possible. Leaders of some industries have taken special care in planning their company towns to make people happy to live there. This way of thinking should be encouraged; it is good investment against mental illness.

Such an approach also makes sense economically. It brings more inhabitants to the area, since it is well planned. The demand for aesthetic values will be greater tomorrow than today. Leisure is on the increase; with more people, there will be more money. A promoter planning to open a new area should have in mind not only the immediate industry but also all other values which will make industry prosperous. Human beings must come first in his mind;

gone are the times when some industrialists used to pack laborers in shacks with no convenience and no social or cultural activity.

Ottawa has a good town-planning scheme, although it is still in its infancy. It will set a fine example when completed. But how much more is still to be accomplished in the remainder of the Ottawa River basin, including Montreal, before the habitat can be made more pleasant for human beings?

In Quebec, public recreation sites close to municipalities are very scarce. Let us hope that there will be other opportunities such as the acquisition of Soulanges Canal and its surroundings, located only 25 miles from the metropolis, which will make a wonderful park for the average Montrealer. We need more and more open spaces for a general public that has more time and greater inclination to visit recreational and educational areas. It is regrettable that between Montreal and Hull there is no managed area for the public. Of course, with the quality of the water being what it is, one should not be greatly surprised. Some residents have had to sell recently built homes, because of the unbearable odors that invaded their rooms and the offensive refuse that settled in beaches and bays. No statistics are available on the losses in property value but it must surely run into millions of dollars.

2. Bathing

The pure waters of a virgin stream have strong attractions for human beings, and bathing is of great recreational value. Public areas must be made available for bathing. The ideal is a sandy beach. If not already existing in the natural state, artificial beaches should be built in accessible areas. The number of people using each one should be limited, so that congestion can be avoided and life made more enjoyable for the majority. Large bathing beaches should be so located that associated noise and activity are isolated from residential areas.

Some administrators have held that, since rivers are the property of no one in particular, there is no objection to their use as sewers; if the water becomes unhealthy, let us forbid bathing and tell the people to build swimming pools. Everyone can see the shortcomings of such a state of mind. First, it is not everyone who likes to bathe in a crowded swimming pool, where the water may be safe at the beginning of the day but may contain many pathogenic germs later on. Similar contamination may even occur

in a river bay. Although typhoid cases have grown rare, doctors do report a high incidence of skin, nose and ear troubles in summer months. In any event, the enforcement of a "no bathing" rule is difficult, especially with children living in summer houses scattered all along the river. But bathing is not the only activity which should be prohibited; water skiing is another.

Are we going to let the water deteriorate to a point where the Ottawa River cannot be approached safely? This unfortunately is already the case in many places, as mentioned in Piché's 1956 report. Furthermore, pollution has steadily increased since then with the increase of population and industry. Increased sewage has not been matched with an overall increase in the flow of water; rather, there has been the accustomed seasonal decrease. The U.S. Health Department has declared that the bacteria count for swimming purposes should not exceed 1,000 per c.c., but at places on the Ottawa River and North River the count has been found higher than 24,000. Aside from the hazard of bacteria, swimming can be ruined by oil and other dumping; equally damaging is weed overgrowth.

Bathing cannot impair the quality of the water in the Ottawa River and its tributaries, unless there should occur a tremendous concentration of swimming within a relatively small bay. The habitat of the fish could be disturbed as a result, but the disturbance is likely to be only temporary. Even if these circumstances become permanent, there is a good case for overlooking any possible damage, when one balances the small area given up against the high value of the recreational facilities it affords. However, to prevent disturbance of an important fish-spawning area, a beach might have to be placed elsewhere, since the habits of fish cannot easily be changed without prejudice to the species.

3. Hunting and Fishing

The Ottawa River supports fish, birds and mammals. To maintain a balance, the natural habitat should be preserved in as primitive a state as possible. We are often in the dark as to the effects of changes we bring into this balance of nature; we do not always know how best to counteract the harm we may be doing.

Pollution is of course the great enemy of aquatic life; it may kill many food organisms used by fish or the fish themselves; it may

drive them away or predispose them to diseases. Undesirable species may multiply and supplant game fishes.

Hunting and fishing are of great value in the recreational field. Their economic importance can be assessed when it is remembered that tourism ranks third as a source of revenue to Canada and is said to represent currently a turnover of $100 million a year in the province of Quebec alone.

For many years the Quebec government has had a policy of granting hunting and fishing concessions and, for five year periods, leasing certain territories to private or commercial clubs (the latter acting as hotel keepers). Until now these clubs have generally contributed by their vigilance, to the preservation of fish and game. Indeed, some of these territories have deteriorated rapidly when opened to the general public.

However, this does not mean that we should necessarily pursue this policy of concessions. In any case, the government is each year breaking up the clubs and obliging a number of them to increase their membership. Perhaps it might be wise to consider renting at nominal cost certain territories to fishing and hunting associations or to other such conservation-minded groups.

In some parks, hunting is forbidden, to the benefit of campers, nature lovers, bathers and others. Yet this should not mean that no animal may ever be killed in times of food shortage or considerable biological imbalance. This is where ecologists must play an important part in policy making.

Our legislation on hunting and fishing is based more on intuition and tradition than on scientific data. We have very few statistics. Generally speaking, we cannot even say with any authority how many fish live in a river or lake, or how many we can take out without impairing the survival of the species. It may be that we remove too many or not enough, or perhaps a large number die natural deaths with no benefit to mankind.

Some people think all we need to ensure good fishing is to restock a river with desirable fish. But each species of animal has so many requirements for survival that our restocking is too often disappointing.

As for the other animals, such as deer, moose, etc. all are affected by contaminated water. Aquatic birds such as ducks can die from an oil slick; this was proved conclusively a few years ago.

Among the fish found in the Ottawa River and the tributaries, sturgeon (Acipenser fulvescens) is the most important for commercial fishing; small-mouth black bass (Micropterus dolomieu), walleye pike (Stizostedion vitreum), northern pike (Esox lucius), lake trout (Salvelinus namaycush), muskellunge (Esox maskinonge), for sport fishing. In the main tributaries, especially the upper one, we have speckled trout (Salvelinus fontinalis) and in the Rivière Rouge and North River, brown trout (Salmo fario) have been introduced. Let us also mention Quebec Red trout (Salvelinus marstoni) in Marble Lake and a few others. On the Ontario side, we find also mouth black bass, bluegill, pikes, etc. There are two interesting species present which are not found either in the Eastern or Western provinces. These are the beaver fish (Amia calva) and the longnose gar (Lepisosteus osseus). They belong to species that lived in prehistoric times, about 200 million years ago.

Introduction of exotic fish must be made with great caution. No one should be allowed to restock without a special government permit. No minnows should be transported from one place to another, since many lakes have been spoiled by undesirable fish which displace game fish or spread parasites. Millions of dollars in tourist trade can be lost through ignorance, carelessness or neglect.

Our fishing legislation unfortunately follows our hunting regulations, and the dates of opening and closing the season usually coincide with breeding. In the case of hunting, where the hunter sees the animal, it is fairly easy to abide by the law. In the field of fishing however, the objectives of conservation are not always realized. A fisherman may be allowed to fish in certain districts but is not permitted to keep certain species. A forbidden fish, hooked and released, will probably die soon after.

If we truly want to protect a given species, spawning territories should be completely closed to fishing. Entire rivers or lakes could thus be out of bounds at certain periods. Conversely, where population and reproduction rates are high, there should be no objection to an open fishing season all the year round. What really counts in the end is the creel limit; each fish taken, whether in or out of spawning season, is one fish less in the water.

There can be no sound legislation until we know a great deal more about our fishes, their habitat and their relation to other organisms. Reliable statistics will have to be kept of their populations, sizes and ages.

For bird hunting we should reserve large ponds on the margin of the river, especially around Carillon in the flooded area produced by a new dam. This could provide an attractive ground.

For the propagation of mammals, some of which, like muskrats, are important revenue producers, special areas should also be provided. Marshes should not all be drained since agricultural fields are often a lesser source of revenue; draining can even be detrimental by removing a natural water reservoir which may be necessary to agriculture itself. Beavers once were Canada's wealth, but now their value is down and their numbers are up; they build dams in many places and sometimes are troublesome.

In some cases the raising of the water level can be favorable for the development of game fish, but it can often be detrimental.

The fashion for farm ponds induces many people to build them. These ponds beautify properties and can, at the same time, bring an appreciable income from fish production. On the other hand, the multiplication of these ponds, usually built on small streams, can contribute to the raising of the water temperature, thus disturbing organisms that require a very specific temperature for their well-being. Careful research should be carried out before over-popularizing the construction of these ponds which, on their own merit, are excellent. In any case, a permit must be sought from the Department of Fish and Game before construction can proceed.

4. Navigation

Navigation has always been, and still remains of prime importance to Canada. The canoes of the *voyageurs* opened the country and their *bateaux* supplied the first settlers.

The Ottawa River can accommodate vessels of 9 feet draught for 125 miles from Montreal to Ottawa, with four canals on the way. Dams and waterfalls preclude navigation in the upper reaches,

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although since 1837 the Rideau canal has provided transit to the St. Lawrence River through Kingston for boats of 5 1/2 feet draught. In 1908, a canal system was projected to afford communication with Georgian Bay; it was shelved at the time but it was revived by the federal government in 1960.

The Ottawa River last year carried 335,000 tons of merchandise, compared to 22 million on the St.Lawrence. The total traffic is not great, but direct communication with Georgian Bay would greatly increase it.

The river is also used extensively by pleasure craft and, in the upper reaches, pulpwood is floated downstream.

Between Ottawa and Montreal there are a few locks, which means damage to the riverbed and interference with the habitat of fish. Where dredging has been performed, the same effect has resulted. The latter operations also stir up matter in suspension to the detriment of the river's amenities, beaches and fishing facilities.

This damage cannot be entirely prevented, but much can be done to reduce it. For instance, by using suction dredgers, the material removed from the bed of the river could be deposited in barges and the silt transferred to settling basins instead of being simply reshuffled within the river.

The transit of boats on a river does not affect the habitat of wildlife, but when we build locks we may allow passage to undesirable fish. This occurred in the Welland Canal, which opened a way for lamprey right up to Lakes Erie, Huron, Michigan and Superior. As a result, lake trout has practically disappeared under the attack of that parasite. Misfortunes of this kind are not easily foreseen or prevented, but research should help considerably.

Motorboats themselves do not in general affect fishing, although they could be a nuisance. In great numbers they could change the composition of water and be the cause of phenolic products. Dumping of oil should be prevented; an oil slick can be a navigation hazard. Dumped organic wastes can cause a weedy overgrowth that may jam the propellers of small craft.

Similarly, constant invasion of waterfowl habitats by boating parties or motorists would eventually drive them away.

Some restrictions should be made as to the kind of motors in use, to reduce the noise, since people who "go to the country" install themselves along the river or a lake for tranquillity and to be far from the noises they have been living with in the city.

It has been demonstrated that noise is a significant irritant to many people. Therefore, noisy boats should be forbidden. Motorboat traffic should be limited to certain routes, keeping clear of the shorelines except in an emergency. The same regulations should apply to sea planes. Good safety measures should be reinforced and dumping of all waste should be prohibited. Commercial navigation, especially around Montreal, should be checked carefully, especially to prevent oil dumping.

5. Water Supply

The water uses discussed thus far - contemplation, bathing, hunting and fishing and navigation - do not depend too directly on the rate of water flow. But now we must consider uses in which the flow is highly important to the economic development of Canada - turbines to produce electricity, industrial processes and domestic uses. For all these needs the Ottawa Basin can only supply the amount of water which it will receive from the sky. Since only some 25 per cent of the precipitation will reach the streams, it follows that we need a great amount of rain or snow to supply our needs. We also require a drainage basin well provided with spongy textured soils and plant life to retain water and deliver it slowly and regularly all year round.

With respect to rainfall the watershed is fortunate. On the Quebec side alone the average is 35 inches per year over 40,000 square miles, which provides a maximum flow of some 300,000 cubic feet and a minimum of 30,000 cubic feet at Grenville.

This flow of water is the life of the basin, like the flow of blood in our veins. Without it, very little development could have taken place. But for optimum benefits this water must be properly managed.

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Domestic uses

(a) Drinking purposes

Water serves many purposes. First and foremost it is essential to life. The simple fact of taking it from a stream causes no damage, unless the water level is lowered to the point which endangers animal and plant life.

Spring water can generally be drunk without prior treatment, but water from the Ottawa River or many of its tributaries must be treated before it is fit for use. The danger of a breakdown or human error in the purifying processes cannot be over-emphasized. It is odd to have to admit that progress and expansion have driven us to drink water which has previously been through sewers. There is no doubt that people would prefer to use unadulterated water, and the day may not be too far distant when we will be obliged to draw water from Laurentian Lakes instead of the Ottawa River.

(b) Cooking

Pure water is indispensable to the cooking of food, otherwise there might be contamination. It is true that boiled water is free from a good number of pathogenic organisms, but does boiling also destroy the many newly identified viruses effectively?

(c) Washing

Washing dishes, laundry or floors with polluted water is not an attractive thought. One might even soil what one wanted to clean.

In the City of Montreal, more than 300,000 gallons of water per day are used for washing and cleansing. A volume of 100 gallons of water per day per person is the usual allotment. All this water, mostly soiled, must run off somewhere. It cannot be stored in one's cellar. In scantily populated places where the soil is adequate, it is directed to a cesspool from which it slowly filters through sand or soil and purifies itself. If there is a freshwater well in the vicinity it may be contaminated, but there is no danger when the cesspool is sited some distance away, say about 150 feet. In the case of non-permeable land, septic tanks can be used, either of metal or cement, with French drains situated over a distance great enough to allow complete absorption of the decanted liquids. These tanks must be carefully watched to prevent contamination and offensive odors.

Where large populations are concentrated, sewers are required and this is where the trouble begins. You start with a small pipe running off into a ditch, and to this first pipe many others are added. All this takes place in the open and gives out a foul smell. In this, insects, rats and of course germs of all manner of disease soon breed. If one could find the time to compile records of the state of health of the citizens of a municipality and the degree of pollution of the air and water, they would probably reveal that the incidence of ill-health is always higher in badly run municipalities.

Dumps are often sited along ravines, so that the first rain will wash everything down. Tons of wastes have been tipped into certain sections of the Ottawa River day after day for years, thus contributing to pollution and causing untold damage: increase in aquatic vegetation due to the fertilizing substances of these wastes, displacement or death of game fish, depreciation of properties, etc.

Yet all this can be avoided to a large extent by the construction of treatment plants. With today's techniques and at a reasonable cost, a purification of 85 to 90 per cent can be attained.

Agriculture

Agriculture may often be established at the cost of also producing erosion-caused pollution; this is because in our country we must clear the forest in order to create arable land, and in so doing we may destroy the spongy water-retaining mantle. To prevent erosion in hilly places good farming methods must be employed. In flat areas, drainage works are sometimes necessary, but the water table must not be lowered too much lest agriculture itself suffer. Before draining, one must ask whether the inundated or marsh area is not better suited to trapping or hunting.

All factors have to be taken into consideration as they affect the conservation of water, and areas of forest and vegetation must be kept so that, by retaining water, they ensure a slow and regular flow. In many instances, such water retention could replace costly man-made reservoirs. Contour ploughing may help keep water in the fields. Portions of fertilizers, insecticides and herbicides used in agriculture are washed down by rain or melting snow and drained to rivers or lakes; organisms may die as a result. Sometimes weed growth is increased. The Ontario side would be

the main source of this type of pollution since the greater share of farmland lies on that side of the river. The minimum dosage of chemicals must be used and there must be research to find products harmless to aquatic life.

Streams should be fenced to avoid pollution by domestic animals, especially cows. Of course, no dead animal should be thrown in a stream.

The effluent from milk and cream plants and cheese plants, very rich in organic matter, should be treated before disposal to avoid ill effects. Of course, all wastes from any agricultural practice should receive some treatment before being released.

Industrial purposes

Water uses for all kinds of industrial purposes are manifold in the Ottawa River basin. Let us run through the main ones:

(a) Electric power

Canada's first hydro-electric power was produced on the Ottawa at Pembroke. Between the Dozois Reservoir and the St.Lawrence River at Montreal the level drops 1100 feet. A river with so many gradients may be harnessed to turbines and generators by means of dams in series.

The total volume of water stored in the reservoirs on the Ottawa River exceeds 11 million acre feet, of which 9.5 million are in Quebec and 1.5 in Ontario.

The total capacity of hydro-electric power is just over 2.8 million H.P. The only important dam that can be added to those already built is actually under construction at Carillon; it will increase the capacity by 840,000 H.P., thus raising the overall total to 3,640,000 H.P. The province of Ontario receives 1,294,672 H.P. from the Ottawa River and Quebec 1,507,904 H.P. The river's power resources are one of Canada's great assets.

In addition to the dams on the river itself, there are many others on the main tributaries. Some serve private interests. Whether public or private, the design and location of damsites should be determined by provincial authorities, so that they may best benefit both public and private interests.

The effects of dams on environment is extensive and should be fully considered both at the time of building and during exploitation.

Generally speaking, dams, especially high ones, result in extensive flooding of the adjacent land areas. These lands are mostly tree covered, and it has not been the general practice to cut the timber before flooding. This is a great pity because the trees left underwater can release considerable quantities of tannic acid which may destroy or drive away aquatic or anismes, particularly fish. It would therefore be most desirable, when economically feasible, that as much timber as possible be removed prior to flooding, not only for the value of the logs, but also because of the possibly disastrous consequences of leaving submerged trees. From a simple aesthetic point of view and for the sake of navigation, the stumps should be taken away.

Dams should be operated carefully, maintaining as far as possible a constant flow of water. If the sluices are closed and the level of water in the river is greatly lowered, aquatic organisms will be exposed and die. If, on the other hand, floodgates are opened too fast, the rushing water will carry everything away; the living organisms will be displaced by the violent current.

So the stream of water must be carefully checked. Thus, where there are dams on several tributaries, concerted action is required and a number of sluice gates should be operated simultaneously. Each will only let through a small volume of water which, when cumulated, will satisfy the needs of the hydro-electric station. Otherwise, a rapid lowering of water level in the reservoir would leave too many organisms high and dry and destroy fish food.

The bottom water of reservoirs has generally a low oxygen content and can cause asphyxiation of the fish. Added to this, water that is feeding the river is usually drawn from the bottom of the reservoir so that further deoxygenated water is brought in. In some cases, it might be necessary to oxygenate this water artificially for the sake of the fish and other animals.

In heavily populated districts where pollution is considerable, an accumulation of waste material can collect in the waters impounded by the dams; occasional draining is required. The wastes should then be sucked out and removed elsewhere; this is better

than simply opening the floodgates and releasing the trash into the river where it may kill many fish and impair the welfare of riverside inhabitants.

A number of dams in the United States have failed in their expectations by silting up and becoming useless in a few years.

If dams do not stop fish from going downriver, they do prevent their ascent; the law therefore requires dam owners to install fishways. Such fishways are necessary, even vital to the reproduction cycle of salmon, but they are not essential for the kinds of fish found in the Ottawa River and its drainage basin. In some cases they might be useful, but also they may be harmful when they allow passage to undesirable species of fish. Instead of obliging companies to build fishways for species of fish other than salmon, and until means have been found to make efficient ones, it would be better to require from the companies payment of a grant towards scientific research into the effects of the dams on habitat. This contribution could be proportioned to the companies' turnover. If a dam caused fish losses, the operator should be required to correct the condition, to replace the fish by restocking of to open up alternative fishing areas.

Fish shooting over a dam from a certain height would kill themselves if they fell on solid ground, but when dropping into water, they easily survive if not too big. Plantings carried out by plane, dropping fish from 100, 200 feet or even higher, have shown no mortality; this was first demonstrated in 1936 in Quebec (Prévost).

What can be said of turbines? Many people think they act as meat grinders; that fish caught in them are minced. Experiments have shown that in slow-motion turbines, such as the Francis type, fish pass through easily without damage (Prévost).

Another form of damage that can result from the damming of a river, if the dam be high enough, is that of changing the river into a lake. Angling sites will then disappear, the aquatic life will be altered, fish species will no longer find the same environment, and species that thrive better in running waters may no longer be caught. On the other hand, for some species, a reservoir, when well planned, may offer several advantages over a river, such as increased food supply, greater living space and so on, and at the

same time can provide a great recreational area.

(b) Atomic energy

With the development of atomic energy aiming at supplementing if not supplanting hydro-electric power, we must expect radioactive wastes to reach the rivers. Some radioactivity, not considered to be at a dangerous level, has been detected near the Chalk River atomic energy plant. Our concern must increase as more such plants are built. It is not possible to assess a safe ceiling for a given radioactive element; animals, such as molluscs, can concentrate some elements up to 600,000 the amount dissolved in water and if this mollusc is eaten by a fish, which later is eaten by man, the radioactive element will finally get into the human system and may cause damage or death. There must be a close, regular check of radioactivity, especially on the Ottawa River, by a skilled team of scientists. This is already being done at Chalk River, but the number of men should be increased.

(c) Forestry and related products

The exploitation of the forest is the greatest activity of the Ottawa watershed. In the year 1959-60, a total of 120 million cubic feet of wood was cut on the Quebec side, and 70 per cent of that wood consisted of spruce (*Picea glauca, Picea rubra, Picea mariana*)and balsam (*Abies balsama*). The greatest activity was along the Ottawa River, where around 24 million cubic feet were cut and the Gatineau River 14 million.

The map shows the concentration of work in the different areas, as well as the different saw mills installed. Most of the resinous woods are used for making pulp and paper, and are floated down the tributaries and the Ottawa River. By this operation, much of the bark leaves the wood and drops to the bottom of the rivers and lakes; the bark deposit may ruin the fish habitat, and the tannic acid and other dissolved material may also cause havoc by changing the composition of the water.

Many dams open at the proper time to control the flow of the wood downstream resulting in the same damage that we mentioned concerning power dams. Dynamite is often used to break a log jam in rapids, and fish may be killed. Some logs sink and smother the bottom; they may destroy spawning beds and ruin the fish habitat.

An illegal practice by some companies, one difficult to control, is that of soaking the bark off the logs by prolonged immersion; the result is a lighter burden on the debarking mill but a littered river bottom. More and more, however, transportation is done by truck; we may hope that before long all wood will be moved this way. Let us also hope that an economic method of debarking trees on the spot will be found. But we must bear in mind that bark left on slopes as loose material will have to be burned or buried so that rain or melting snow will not wash it down into the streams.

Sawdust from sawmills should not be placed along the banks of a stream or a lake, and a law should specify the location for each. Today, several industries burn their bark in modern furnaces and are able to recover steam-heat which they can use in their manufacturing processes. So much the better for the purity of our rivers!

The main mills are located at Ottawa, Hull, Gatineau, Temiscaming, Buckingham, Masson, Hawkesbury, St. Jerome and Mt. Rolland. They require vast quantities of water for the manufacture of pulp and paper. It is important that their water should be as pure as possible, otherwise they will have to treat it at extra cost. These industries might eventually have to move elsewhere if they cannot find adequate supplies of water.

Road building usually calls for tree felling, dynamiting and displacement of gravel. One often overlooks the fact that this will usually hasten erosion, especially in the proximity of a stream. Bulldozers and other earthmovers should not be allowed to clutter rivers with loose material which will ruin the aquatic habitat. Road embankments, railway tracks and abandoned roads should be seeded or replanted to prevent erosion.

The use of pesticides to destroy harmful insects is a great threat to aquatic organisms and other fauna. After spraying with D.D.T. or similar products by air, these substances lay on the ground and are carried away by the next rainfall into the streams where they gather in concentrations strong enough to destroy aquatic organisms. Quantities must therefore be limited to a strict minimum and aerial operations carefully watched.

For newsprint production one mill alone discharges to the Ottawa River each year, 7,000 tons of fibres and 20,000 tons of

bark; each day the sulphite liquor totals one million gallons. If we add to that the wastes from other mills we see the enormous quantity of material which is thrown in day after day. This increases the amount of organic matter, already naturally high in the Ottawa River, so that in some spots at some times oxygen is reduced to the point that fish die of asphyxiation. The wastes are an excellent medium for the propagation of bacteria, which can be detrimental to human and animal life. All solids, even those of inert composition, will cover the bottom of the river and spoil the natural habitat; close inspection may reveal a mat many feet thick.

Although some methods of preventing pollution by the pulp and paper industry are known and could be used, much is needed to reduce the cost. The ideal solution would be to transform waste into by-products. This is what industry is trying to achieve, thus far without much success. Only alcohol and several secondary products have been successfully manufactured.

Mines

Close to the head of the Ottawa River are the famous mines of gold and copper at Rouyn-Noranda, wastes of which have destroyed fish and practically all animal life in the adjacent lakes. In other places, we note extraction of calcium, iron, feldspar, granite, magnesite, molybdenite, dolomite, lead, silica, zinc; all these, to some small extent, pollute our waters. Sedimentation lagoons could be valuable here.

Textiles

There are 6 textile mills on the Quebec side.

This industry requires great quantities of water as pure as possible; usually it must be treated before use. The wastes are very harmful, but their danger can be reduced by usin fine mesh filters, maintaining good aeration in the sedimentation lagoons, provoking chemical precipitation and ending the treatment with a bio-filter.

Tanneries

Water is again necessary for the processing of leather, but to a lesser degree than with textiles. The resulting sewage has a revolting odor but can be adequately treated by various processes such as chemical precipitation and filtration or else by coagulation and sedimentation.

Other industries
I do not intend to list all the kinds of industries to be found in the Island of Montreal, requiring over 300,000,000 gallons of water a day. A single refinery devours up to 35,000,000 gallons. Unfortunately, all these plants pollute the water of the river Ottawa that surrounds the Island of Montreal and Ile Jésus.

6. Waste carrier
This title may surprise the conservationists, since practically any waste is bound to impair the quality of water and be contrary to the established laws. That is true, but we must realize that, with the development of industry and population, it is practically impossible not to have waste in our streams. There is however a great difference between the present general practice of throwing everything in the river and the policy of retaining most of the waste by methods already known. Here we must consider not only the waste that we deliberately throw into our water, but also that which reaches the rivers independently of our will.

Those who have claimed that dilution and self-purification were sufficient to take care of used waters can see today where this harmful policy has driven us when they see the offending condition of the Ottawa River between Ottawa and Montreal.

Our streams and lakes have been turned into open cesspools. Self-purification may perhaps improve the water far downstream from the source of pollution but what can be said for the closer neighbourhood? Diluting soiled water to camouflage pollution is always successful because, for example, currents of different densities do not mix and molecules have between themselves a real force of cohesion. You only have to glance at the demarcation line between the waters of the St. Lawrence and the Ottawa which shows up downstream even south of Three Rivers. If dilution worked so well, the difference in the degree of pollution would not be so great between the water in the middle of the St. Lawrence and that which bathes the shores of Montreal Island. This does not mean that one cannot, to some extent, rely on dilution and self-purification acting further upon waters already purified to the maximum extent.

As it is not possible with our present methods to obtain 100 per cent purification, we shall require these phenomena to conclude our cleaning processes and we shall need all the water we can get.

This leads me to protest against any diverting of water that might reduce the flow of a river. In some cases, we shall even have to build storage reservoirs to supply our needs in times of drought. Our rivers will not only have to take care of domestic and industrial wastes, but also of all that is carried down during storms. We might also ponder whether we should not build sedimentation tanks to collect surface waters. These tanks would hold back silt and other solids washed down by the rain.

Even with the best purification plants available, we cannot prevent nitrates and phosphates from fertilizing our waters and stimulating the growth of harmful algae. Furthermore, detergents come through unscattered; they have been detected as far as 1000 miles downstream. You are quite likely to drink water containing detergents, because the chlorination that takes place in filtering plants does not alter their nature. What the ultimate effect on human beings will be, no one can say.

The nuclear tests recently undertaken by Russia have tremendously increased the amount of radioactivity in the air which finally reaches the water and pollutes it. The recent reference to poisoning of ducks by radioactive material following nuclear tests is quite a warning of what can happen. There are many gases such as hydrocarbons, sulfurous components, fine solid particles such as fly ash..etc. which eventually pollute water. The noxious effects are first felt while they are in the air, but since those reservoirs containing water for drinking or alimentary purposes are usually open, they, too, will become contaminated by fallout.

Cost and benefits

The economic importance of the Ottawa river watershed rests mainly on its proximity to Canadian population centers; generally speaking we find here a population of nearly 2,000,000 inhabitants which represents two fifths of the province of Quebec. It is obvious that the Montreal region suffers from pollution. If the wastes from the Montreal area are added, no one will be surprised to find the St. Lawrence polluted as far as Quebec City and beyond, to the wholesale detriment, not only of the riverside dwellers, but also of all that region which is of such vital importance to Quebec's economy.

We cannot hesitate. It is most urgent that the increase in

the pollution of our waters be stopped and, next, that used water be adequately treated. We still meet some people who lag behind and are opposed to these plans on the pretext that "it will cost a lot and won't pay" Such an attitude is contradicted by the facts, if you take time to look into them. The costs of building and operating a purification plant for the treatment of domestic sewage amounts to less than a penny a day per person, which is very little compared to its advantages. There is nothing to be feared, especially when each municipality can generally receive federal and provincial help. In the Province of Quebec, the Municipal Affairs Commission examines the financial situation of municipalities and reports to the Water Purification Board.

In the past, we must admit, some of our industries were loath to treat their wastes because of the cost and because "others" were doing nothing: in a way, you can't blame them for their line of thought. But on the other hand, other industrialists, perhaps more civic-minded, have stepped forward and set an example; they also benefited from this. In this field as in others, an example starts the ball rolling. If the great industries decide to treat or improve the treatments of their wastes, the day will be won.

In future, industry will always have to reckon with the cost of water purification in its operating cost. Water pollution is such a serious matter, such an urgent matter that the governments should consider, when real financial difficulty is met, some form of fiscal rebate to the industries that will purify their waters or prevent pollution. The governments could rely on reports prepared by an economic committee. On the provincial scale, the Water Purification Board has already an Advisory Board chosen from several fields, which could fill that duty.

Water pollution in the province of Quebec is such that it means a real loss of millions of dollars; it is obvious that both prevention and control of water pollution are costly at the start. But it is also certain that the economy at large will benefit. The "money" question, important as it is, must not overshadow the purely human interests. Our population has an absolute right to the usage of natural resources. Unpolluted lakes and streams are a capital investment, as are outdoor sports. Is not a Sunday angler who whiles away a few hours dipping his line off the quay side or from a boat just as contented as the millionaire who flies at great cost to seek his game in the distant lakeshores of Ungava?

Water purification is therefore an economic and humanitarian necessity.

Conclusion

Some administrators advocate the classification of rivers such as for drinking purposes, bathing, domestic, industrial uses. This might at first sight seem logical, but it is not too practical in a country which is in active development, such as our own, since this would rouse many sharp differences of opinion and lead to switches of classification. It seems better to state that anyone who has waste to deliver in our waters must use the best known equipment to prevent pollution. Then a maximum permissible concentration of waste elements should be established by the Water Purification Board and this independently of the volume of the receiving waters. However, a permissible maximum total amount of waste produced by all involved will have to be determined in relation to the minimum flow of the river; otherwise no new development should take place, unless there is some improvement in the methods of water purification.

In summary, any change of the nature of the water should be prevented, especially if such a change produces an excessive bacterial, physical or chemical contamination, or if unnatural deposits interfere with navigation, fish and wildlife, bathing or recreation or destroy aesthetic values, or produce toxic substances and materials with objectionable tastes and odors. If we do the utmost to prevent this, Canada will thrive; otherwise we shall be engulfed by pollution, and life will become unbearable. After all, we live on earth and not in outer space, at least not at the present time. If so many millions of dollars are spent to reach the moon, why should we not spend some to live in happy surroundings. If in the past people have been accustomed to a certain extent to live with water pollution, they should react now and combat it since they have means to do it. River boards made of citizens who are far-sighted in the development of their region should be formed forthwith, not for the purpose of fining people, but of convincing them, because I believe that conviction (persuasion) will give better results than conviction (condemnation).

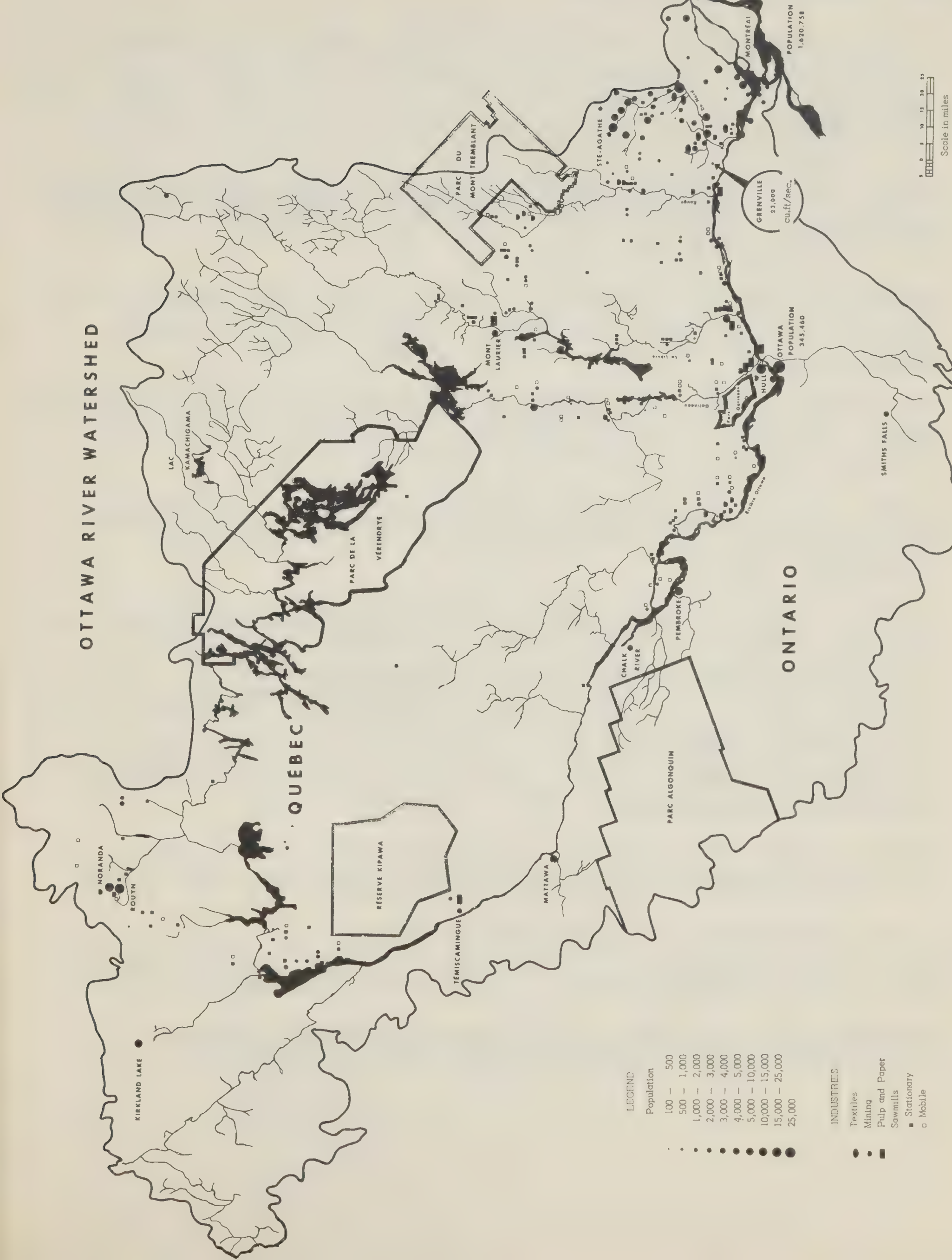
On the technical side, the first step must consist in putting a research team to work to make a thorough survey of the Ottawa River watershed; the object is that of setting up a policy for

making the most of the water for all its uses, i.e., a policy of equi-marginal utilization. Low altitude aerial photography is an early need; specialists must study the photographs to become intimately acquainted with the area, doing much of their work indoors. Then the outdoor work can be undertaken by landscapers, biologists, engineers, geographers, geologists, sociologists, etc.

In order to make maximum present and future uses of our natural resources the conservation principles enumerated throughout this brief paper must be borne in mind.

Further, it is indispensable for the provinces of Ontario and Quebec to follow a common policy. Whichever province has the stricter regulations should set the standards for the other, as is done among the states of our neighbouring country. How simple it would be if sound international standards were everywhere followed. But perhaps that is asking too much of a world out of tune. At the beginning we stressed the need for setting up ideals, but this particular one seems beyond our present reach.

But if everybody is really co-operative and is sincerely convinced that pure water is prerequisite to any development, then we see no reason why our other ideals cannot be attained. Success is not a matter of techniques alone, but also of people's minds. Since we live in a democratic world, we need to foster public enlightenment and only then will we be able to use the Ottawa River and its watershed to the best advantage of the present and future generations.


OTTAWA RIVER WATERSHED
QUEBEC
ONTARIO
MONTRÉAL
POPULATION 1,620,758
STE-AGATHE
PARC DU MONT TREMBLANT
GRENVILLE 23,000 cu.ft/sec.
OTTAWA POPULATION 345,460
HULL
MONT LAURIER
LAC KAMACHIGAMA
PARC DE LA VÉRENDRYE
SMITHS FALLS
PEMBROKE
CHALK RIVER
PARC ALGONQUIN
MATTAWA
TÉMISCAMINGUE
RÉSERVE KIPAWA
NORANDA
ROUYN
KIRKLAND LAKE
Scale in miles
LEGEND
Population
100 – 500
500 – 1,000
1,000 – 2,000
2,000 – 3,000
3,000 – 4,000
4,000 – 5,000
5,000 – 10,000
10,000 – 15,000
15,000 – 25,000
25,000
INDUSTRIES
Textiles
Mining
Pulp and Paper
Sawmills
Stationary
Mobile

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AIR POLLUTION AS A CANADIAN REGIONAL PROBLEM

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1. Introduction

Air pollution problems have been multiplying steadily in Canada with the growth of population and industry. Many of these problems are typically urban in character as they are related to the activities of the general population in the consumption of fuels for heating, power and transportation and specific emissions of pollutants from industry concentrated in the urban environment. However, there are other complex aspects not related to the concentration or distribution of population but rather to the operations of certain heavy industries that result in by-products that are economically or technically difficult to recover or control. The discharge of relatively large quantities of such contaminants to the atmosphere as sulphur dioxide, volatile fluorides, and other acid gases has been accompanied, in certain instances, by injury to farm crops, ornamental plants, forests and soils. Other effects include economic damage from the accelerated corrosion and deterioration of metals, stonework and other materials of construction, paints, textiles, rubber and other goods, vehicles and many other products. Some localities suffer from a recurrent odor nuisance due to the presence in the air of small quantities of hydrogen sulphide, mercaptans and other malodorous substances. Other communities are subjected to the excessive deposition of dust from solid fuel-burning installations, blast and open hearth furnaces, cement manufacturing and various high temperature processes.

Although the above aspects of air pollution may be assessed readily by direct chemical and biological studies or economic surveys, the effects on human or animal health are much more subtle and difficult to determine. Canada has, fortunately, escaped major, acute episodes resulting in deaths and illness, such as those that

have been reported in the Meuse Valley of Belgium [1], Donora, Pa. in the United States [2] or London, U.K. [3]. Nevertheless, minor effects involving eye and skin irritation and odors have been experienced in a number of Canadian communities. Certain chronic aspects of urban air pollution on health are under investigation in Canada but no concrete findings have been reported as yet. However, studies in the United Kingdom, the United States and elsewhere suggest relationships between air pollution and the incidence of lung cancer, chronic bronchitis, emphysema and other respiratory diseases.

The atmosphere is one of our most important renewable resources. In its natural state, the air of the lower atmosphere consists of about 78.09 per cent by volume of nitrogen, 20.95 per cent oxygen, 0.93 per cent argon, 0.03 per cent carbon dioxide, 18 parts per million of neon, about 5 p.p.m. of helium, 2 p.p.m. of methane and smaller amounts of krypton, nitrous oxide, hydrogen and xenon. Water vapor may be present in the range of 5000 to 20,000 p.p.m. by volume when the relative humidity is of the order of 25 to 100 per cent. A small amount of dust is also a normal component of the atmosphere and consists of micro-organisms, plant spores, pollen, soil and vegetation particles, salt from ocean spray, and particles released through volcanic activity. These substances are rendered airborne through the action of winds and other meteorological factors. In the aggregate, such particulate matter seldom reaches levels in excess of about 50 micrograms per cubic meter of air in the unpolluted atmosphere.

The maintenance of a reasonable state of air purity is essential to all human, animal and plant life. The average adult requires about 15,000 to 20,000 quarts of fresh air per day, or ten times as much by weight as the total amount of food and water consumed daily. It is fortunate that nature has provided a huge reservoir of the above mixture of gases and the changing temperature and pressure system necessary to ensure constant mixing by air circulation currents of the contaminants released by the activities of man. However, these natural mixing processes may, on occasion, proceed at a slower than normal rate. Fog, temperature inversions and calms may result in stagnant air. Under such conditions the continued discharge of contaminants may cause rapid increase in concentration levels and this buildup will persist until natural air cleaning processes can again become operative.

Our concern with the state of the air in urban areas relates not only to the presence of smoke and other visible fumes or solid impurities but to invisible emissions of a variety of gases and vapors and the resultant chemical and photochemical combinations among them in the atmosphere.

We may define community air pollution as a condition of the ambient atmosphere that is due to the presence of substances, liberated by the activities of man, in concentrations sufficient to interfere directly or indirectly with his comfort, health or safety, or with the full use and enjoyment of his property. This definition rules out such natural sources of pollution as volcanic activity, dust storms, combustion products of forest fires, airborne pollen, bacteria, plant spores and agents of communicable disease. It is beyond the scope of this paper to deal with the problem caused by the discharge of radioactive waste products to the atmosphere from nuclear reactors or bomb tests.

2. Nature of Pollution

Substances that contribute to the pollution of the community atmosphere may be divided broadly into two classes:

(1) (a) True gases and (b) vapors consisting of volatile compounds that have in general a boiling point range below about 200°C.

(2) Particulate matter containing both solid and liquid particles over a wide size range. These particles may be classified according to size into (a) relatively coarse material in the diameter range of over 100 to about 40 microns; (b) intermediate size aerosols from 40 to about 10 microns; (c) respirable aerosols of less than 10 to about 0.1 micron diameter; and (d) submicron aerosols and nuclei of less than 0.1 micron size.

Only a relatively small number of compounds have been identified, thus far, among the thousands of substances that pollute the air as a result of man-made activities. Some of the difficulties involved in the isolation and identification of these substances are due to their complexity, the low concentrations in which they occur, their labile nature and the fact that many volatile or gaseous products are strongly absorbed on the co-existing aerosol particles.

Waste products of one sort or another are discharged to the atmosphere in every type of fuel-burning operation incineration, or manufacturing process. Among the major sources may be listed the combustion of coal, oil and gas for power generation, steam and heating purposes; the combustion of gasoline and other fuels in internal combustion engines for transportation purposes; oil refining and petrochemical processes; iron and steel production; smelting and refining of ore concentrates; the production of chemicals, food products, pulp and paper, cement and fertilizers, solvents, paints, plastics and many other products.

Gases and vapors are normally present in the atmosphere in concentrations of less than one part per million parts of air by volume (p.p.m.), with the exception of carbon dioxide and carbon monoxide. Carbon dioxide is not usually considered to be an atmospheric contaminant, except under special environmental conditions, because of its role in the photosynthesis of green plants. The most common gaseous contaminants in community air are carbon monoxide, sulphur oxides, hydrogen sulphide, oxides of nitrogen, hydrocarbons, aldehydes and ozone or "oxidants". Sulphur dioxide is liberated in the combustion of coal, oil and other fuels and in the smelting or sintering of metal sulphide concentrates. The most prolific source of carbon monoxide, hydrocarbons, aldehydes and oxides of nitrogen is in the exhaust gas discharged from the numerous automobiles, trucks and buses operating on city streets and roads.

A considerable amount of information on the concentration and composition of particulate contaminants in city air has been published from studies of the Windsor-Detroit international pollution problem under the terms of a reference to the International Joint Commission[4] and from results of the U.S. National Air Sampling Network.[5] The average concentration of airborne particulate matter varies roughly in proportion to population. Thus, in cities of over 2 million in population, the average particulate matter concentrations vary from about 200 to over 350 micrograms per cubic metre of air. Those with populations between 500,000 and 2 million show average atmospheric concentrations in the range of more than 100 to about 180 micrograms per cubic metre. However, atypical dust loadings may be evident in communities that are relatively small but are dominated by a strong dust source of either industrial or natural origin.

In so far as the composition of this complex mixture of particulate substances has been studied by analytical, spectrographic and other techniques, there are in evidence certain similarities and also qualitative differences in fractional components from one city to another, probably indicative of dominant sources of pollution. For example, the filtered dust may be separated into acetone-soluble or benzene-soluble organic material, a protein fraction, and substances that contain more than twenty metal elements in the form of oxides, carbonates, chlorides and fluorides, sulphates and nitrates. There is also present a well-defined polycyclic hydrocarbon fraction that contains small amounts of compounds possessing toxic carcinogenic properties such as benzpyrene, di-benzpyrene, benzanthracene and others. In particulates collected from the Windsor-Detroit atmosphere, the following metal elements have been found by spectrographic analysis, in descending order of abundance; calcium, aluminum, silicon, iron, magnesium, lead, zinc, manganese, copper, titanium, tin, tungsten, chromium, molybdenum, barium, bismuth, nickel, antimony, cadmium, vanadium, and beryllium[4].

As an indication of the major influence of traffic gas from the operation of more than 2.5 million vehicles in Los Angeles County, this area has the highest concentration of acetone-soluble particulate matter and nitrate ion in comparison with other large metropolitan complexes such as New York, Chicago, Philadelphia, Detroit and San Francisco in the U.S. National Air Sampling Network. Furthermore, average lead concentrations in air are relatively greater in those large cities having populations of 500,000 or more than in smaller urban centres, presumably due to the increased consumption of automotive fuel, among other factors.

Within recent years, an increasing number of polycyclic hydrocarbons have been identified in the particulate phase of urban air and in that of exhaust products from gasoline and diesel engines[6,7,8]. Of these compounds, a number are known to be carcinogenic on the basis of animal tests, including 3,4-benzpyrene; 3-4-benzo-fluoranthene; 1,2,3,4-dibenzopyrene and 1,2,4,5-dibenzopyrene. These toxic compounds are formed in the incomplete combustion of solid, liquid and gaseous fuels, in association with smoke, soot and tarry material. Their presence has lent support to the theory of the existance of an aetiologically significant factor in epidemiological studies of the greater incidence of lung cancer in urban over rural populations.

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3. Pollution Trends

It is natural to infer that pollution trends in Canada, as in other countries, are influenced by the growth and distribution of population and industry. Most of the population of Canada is concentrated in urban and industrial communities as a result of the rapid increases in industrialization and in population growth that have taken place since the end of the Second World War. The population attained an estimated level of 18 million during 1960 compared with approximately 11.5 million in 1941 and 14 million in 1951. About twice as many people now live in urban as contrasted to rural areas. According to data in the Official Handbook of Canada, the population residing in the metropolitan areas has increased by 55 per cent over the past two decades as compared with a 40 per cent increase in the total number of people. By 1956 there were 6,282,000 persons residing in only 15 metropolitan areas of Canada, accounting for 40 per cent of the total population and about 60 per cent of the urban population. This shift from rural to urban areas has been accelerated in the last two decades. In 1941 the male labor force employed in agriculture consisted of about one million persons or 33 per cent but by 1951 it had decreased to 730,000. This downward trend has continued so that those employed in agriculture now constitute less than 20 per cent of the total male labor force.

Coincident with these population changes, there has occurred a tremendous expansion in mining and manufacturing industries so that Canada now ranks sixth in manufacturing output and fourth in total trade value of commerce among the nations of the world. These remarkable achievements have been made possible by the abundant natural resources of Canada in forests; rivers and lakes for the provision of cheap hydro-electric power; deposits of minerals containing nickel, copper, uranium, iron, lead, zinc, asbestos, gold, silver, platinum and other useful metals; and the discovery and development of oil and gas fields. Since the last war there have been equally significant increases in industrial production associated with the manufacture of iron and steel products, synthetic rubber, pulp and paper, petrochemicals, elemental sulphur and fertilizers, oil refinery products, automotive vehicles, aluminium products, cement and building materials and many other goods. By the end of 1959, electric power generating capacity reached a level of 21,157,000 kw., representing an increase of 250 per cent in ten years.

Great concentrations of light and heavy industry have developed in the Greater Montreal and Metropolitan Toronto areas. The population of the Montreal metropolitan area is about 1,750,000; that of Toronto, 1,500,000; Vancouver, about 750,000 and Winnipeg, approximately 500,000. There is an almost continuous belt of urban and suburban development with interspersed light and heavy industry in the sprawling region embracing Oshawa-Toronto-Hamilton-Niagara Falls. Many industrial activities are located in the narrow belt along the upper St. Lawrence River from Montreal to Kingston. Important segments of manufacturing operations are contained in the region embraced by Guelph-Kitchener-Brantford-London-Windsor-Sarnia in Southwestern Ontario. In the Atlantic Provinces, significant mining and industrial activities are associated with coal, iron, fluorspar and gypsum production, the manufacture of steel, pulp and paper, other wood products, oil refinery products and various goods associated with light industry. British Columbia and Alberta have also witnessed phenomenal expansion in mining and manufacturing. Large increases in the production of petroleum and natural gas have taken place in the last ten years. Canada has become an important producer and exporter of elemental sulphur as a by-product of the purification of sour natural gas. Within a few years, it is anticipated that the production of this element will exceed 3 million long tons annually.

About 50 per cent of Canadian manufacturing output is located in Ontario, 30 per cent in Quebec and nearly 10 per cent in British Columbia; the remainder being distributed in the other provinces, the Yukon and the Northwest Territories. Manufacturing also ranks as the leading industry in Newfoundland, Nova Scotia, New Brunswick and Manitoba. As many Canadians are now employed in manufacturing as there are in the combined activities of farming, forestry, fishing, mining and construction. The gross value of manufacturing production has now reached a level of about $22.5 billion.

(a) Sources of Air Pollution

Sources of air pollution may exert a harmful influence on natural resources, such as soils, farm crops and forests, to a degree that depends upon both local and regional aspects of topography and climatology. The possibility of damage to such resources from the atmospheric waste products of man's activities is greatly enhanced if the local and regional topographic and meteorological

factors are unfavorable for the rapid dilution and dispersion of contaminants. In such cases, more or less elaborate control measures must be applied by industry to recover or reduce harmful pollutants at the source, if a serious damage problem is to be avoided.

The major sources, by far, of air contaminants from the activities of man are the products of combustion released in ever-increasing quantities through the use of fuels for domestic and industrial heating purposes, power generation, transportation and other purposes. In keeping with the strong upward trend in industrial production during the last decade, new air pollution problems have arisen in Canada while existing ones have been intensified by such sources. Apart from the emissions resulting from the combustion of fuels, important sources of contaminants exist in the atmospheric waste products of the iron and steel, non-ferrous metal smelting and refining, oil refining and petrochemical, general inorganic and organic chemical, pulp and paper, and many other process industries.

Within recent years there has been increasing emphasis placed upon emissions of hydrocarbons, other organics and oxides of nitrogen by virtue of the possibility of photochemical interactions between such products after release to the atmosphere. In the past, the greatest concern has been exercised over the control of smoke, dust and sulphur dioxide emissions. However, waste exhaust products from the internal combustion engine are assuming prominence in atmospheric pollution studies in the light of experience in the Los Angeles area. Within Canada and the United States, the consumption of solid fuel has been decreasing and that of liquid gaseous fuels has been rising steadily, especially in fuel usage for space and water heating. This trend has aided local abatement efforts in the control of smoke, dust and sulphur dioxide in a considerable number of urban areas.

Sulphur dioxide remains as one of the major contaminants not only on an area-wide basis but also from specific, more concentrated sources such as the metal smelting and oil refining industries and large coal-fired, electric power plants. It has been estimated by Katz and Cole[9] the the annual emission of sulphur dioxide from a group of nickel-copper smelters in Canada has been as high as about 3 million tons during peak production years. Within the

United States from available statistics[10], the annual emission of contaminants from fuels of all types is as follows: smoke, 5 million tons; dust and ash, 7 million tons; sulphur oxides as SO_2, 19 million tons; and miscellaneous gases and vapors, such as nitrogen oxides, ammonia, gaseous and volatile halides, hydrocarbons and other organics, 42 million tons. Of the latter total, nitrogen oxides, expressed as nitrogen dioxide, amount to 8 million tons; halogen compounds about 2 million tons; organic products in emissions from the combustion of fuels, 21 million tons; and losses by evaporation of gasoline, other hydrocarbons, solvants and miscellaneous organics, 11 million tons.

Smelting operations, in particular, have been the cause of heavy damage to agricultural and forest areas and sulphur dioxide in the atmosphere has contributed to a major extent to the deterioration of materials such as metals, stone, cement, paper, paint, leather and textiles. In 1926 to 1930, the emission of this gas from the stacks of the large lead-zinc smelter at Trail, British Columbia, attained high levels, with a maximum of about 20,000 tons per month. As a result, widespread damage to agricultural crops and forests occurred both in Canada and in the adjacent part of the United States within the northern part of Stevens County, Washington State The ensuing international litigation over this problem led to a pioneering effort on the part of the company involved to control this nuisance. Within the next decade a large new industry was created to convert the waste sulphur gases to sulphuric acid, ammonium sulphate, ammonium nitrate and phosphate fertilizer. Today, the Trail Smelter recovers about 91 per cent of the sulphur dioxide, formerly wasted, by conversion into these valuable by-products. The Trail recovery plants have a capacity of 1,300 tons of 100 per cent sulphuric acid and of 240 tons of synthetic ammonia per day, besides the necessary plant capacity for the production of the above fertilizers [11,12].

Both in the United States and in Canada there is an increasing trend to control atmospheric pollution in the smelting and oil refining industries through the recovery of waste sulphur dioxide and hydrogen sulphide by conversion to sulphuric acid of elemental sulphur. The latter by-product is usually the favored one where hydrogen sulphide from oil refining or processing of sour natural gas is concerned.

(b) International Windsor-Detroit Problem

The impact on air pollution trends of expanding industrial transportation and urban developments along international segments of the Great Lakes - St Lawrence Seaway system is illustrated by the problem of the pollution of the atmosphere in the Detroit River Area. In January 1949, the Governments of Canada and the United States agreed to a joint reference of this matter to the International Joint Commission. The Commission was requested to enquire into and report to the two Governments upon the following questions:

(1) Is the air over, and in the vicinity of, the cities of Detroit and Windsor, on either side of the international boundary, being polluted by smoke, soot, fly ash, or other impurities, in quantities detrimental to the public health, safety or general welfare of the citizens, or to property interests on either side of the international boundary line?

(2) If the foregoing question, or any part thereof, is answered in the affirmative, to what extent are vessels plying the waters of the Detroit River, or any of them, contributing to this pollution; what other major factors are responsible and to what extent?

(3) If the Commission should find that vessels plying the waters of the Detroit River, or any of them, are responsible for air pollution to an extent detrimental to the public health, safety or general welfare of the citizens, or to the property interests on either side of the international boundary line,

    (a) what preventive or remedial measures would, in its judgment, be most practical from the economic, sanitary and other points of view?

    (b) what would be the probable cost of such measures?

    (c) by whom should such cost be borne?

The Commission appointed a Joint Technical Advisory Board to conduct the necessary studies in the area covered by the Reference. After a lengthy investigation by this Board, with the assistance of many government agencies, industrial and shipping

interests, the Commission presented a final report on the findings and recommendations to the two governments in June, 1960. Some interesting information is available in the published Report[13] on the sources and emissions of contaminants in this area.

The Greater Windsor-Detroit Area is the third largest manufacturing center in North America, although it is the fifth largest in population. Its manufacturing employment is exceeded only by New York and Chicago. Approximately 3,250,000 people live in the international metropolitan area. The extensive industrialization, dominated by the automobile and primary metals industries, together with the extensive use of coal and other fuels, use of vehicular fuels, burning of refuse, and a wide assortment of other activities, gives rise to a large atmospheric pollution load.

Generally speaking, annual fuel usage consists of about 13 million tons of coal, 4.3 million tons of fuel oils, and 3.8 million tons of natural gas. Daily use of gasoline is about 3.4 million gallons and of diesel fuel, 42,000 gallons. An estimated 1,235 tons of refuse per day are burned in municipal incinerators, 1,300 tons in domestic incinerators, and 400 tons in commercial and industrial incinerators.

Blast furnaces and steel mills comprise a significant proportion of the manufacturing activity in the area. About 7 million tons of pig iron and steel are produced each year. There are also about 30 iron and steel foundries producing about 4,300 tons of castings per day. Approximately 100 establishments are engaged in nonferrous founding and secondary metal refining. About 40 per cent of all manufacturing employees work in plants producing automobiles, trucks, and buses, and parts for them. The chemical industry comprises some 200 plants and petroleum refining is conducted on a considerable scale. A host of other industrial activities also contribute to pollution of the atmosphere Solvent losses to the atmosphere from use of paints, dry cleaning, plastics molding, gluing, degreasing, etc. constitute a sizable atmospheric pollution load.

Vessels of the Great Lakes System, plying the Detroit River, contribute to pollution of the atmosphere by emissions of black smoke, fly ash, and gaseous contaminants from the combustion of coal and oil. The proportion of the total pollution emissions in the

area attributable to vessel operations is quite small. However, the emissions from vessels are concentrated along the river and are particularly objectionable because of the close proximity of residential, recreational, and civic land uses at many points along the river. Since 1952, a major reduction in pollution from this source has been effected through the operation of a voluntary control program and conversions of vessels to more efficient fuel-burning installations.

An approximate inventory of the principal pollution emissions to the atmosphere from all of man's activities in the area was made in 1955. Emissions to the atmosphere in the Canadian portion of the area were found to be about 10 per cent of the total, the remainder being discharged in the United States side. A grand total of 4,000 tons of gases or vapors and 770 tons of solids are discharged daily, excluding carbon monoxide or carbon dioxide, on the basis of this inventory. The actual pollution load is greater than that estimated here by a considerable margin due to the fact that much of the information required was not available. As this area continues to grow in population and industrial activity, the pollution problems will become more acute.

4. Research

(a) United States Research Activities

The United States Public Health Service sponsored a National Conference on Air Pollution which was held at Washington, D.C., in November 1958. The recommendations of this Conference stressed the need for intensified research into the nature, causes, effects, and abatement of air pollution. Following this meeting, an Advisory Committee was established to formulate national goals for air pollution research. The Report of the Surgeon General's Ad Hoc Task Group on Air Pollution Research Goals released late in 1960[14] is of considerable interest to Canada, as many of the growing problems of community air pollution in the two countries are essentially similar in character and complexity although they may differ in magnitude.

The recommended research tasks have been divided into 10 principal categories, as follows:

(1) Effects of air pollution on human health.

(2) Agricultural effects resulting from air pollution damage to crops and animals.

(3) Economic losses due to damage to materials, soiling and reduced visibility.

(4) Measurement and identification.

(5) Meteorological factors affecting air pollution.

(6) Atmospheric reactions leading to the formation of new pollutants.

(7) Surveys and monitoring.

(8) Control methods and equipment.

(9) Information, education and training.

(10) Administrative and legal aspects.

The recommendations of the above committee advocated about a three-fold progressive increase in the nationwide research effort on air pollution from the current estimated level of about $11 million annually to approximately $32 million per year by 1968. About 40 per cent of this maximum annual expenditure was considered to be the responsibility of the federal government, 28 per cent the responsibility of industry, and 32 per cent the responsibility of states and local governments. The following general criteria were employed by the Task Group in the allocation of these responsibilities:

(a) The federal government should be largely responsible for research of a broad nature and of general applicability such as determining criteria for air quality; for the collection, integration and communication of information; and for the training of specialized personnel;

(b) The responsibility of industry for air pollution research relates primarily to the development of adequate and economical control equipment and procedures, and to other studies specific to emissions of individual industries;

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(c) States and local governments have the responsibility to support research of primary interest to them and to survey and evaluate the air pollution problems of their respective jurisdictions.

Although there is a considerable degree of variation in the estimates which have been made of the economic losses in the United States due to air pollution, the more recent estimates of these costs have ranged from $4 billion to $7.5 annually, including agricultural losses and those arising from corrosion, soiling and other damage to materials but excluding costs related to impairment of health. These annual losses are equivalent to about $23 to $43 per capita. For Canada, the equivalent total annual costs would range from about $400 million to $775 million.

(b) Canadian Research Activities

Research at the federal level in Canada on the toxic effects of air contaminants and related problems of sampling, methods of analysis and identification are centralized largely within the Occupational Health Division of the Department of National Health and Welfare. Divisional activities are organized into two main units of environmental assessment and biological studies. The environmental assessment unit is concerned with laboratory studies and the provision of services to other federal departments, provincial health departments, municipalities and other agencies in the investigation of conditions that are actually causing or may lead to a health hazard. At the request of provincial health authorities, surveys of air pollution have been organized in a number of Canadian provinces with financial assistance under the federal health grants. Other projects deal with studies of dust and gaseous concentration levels in mines, the extent of environmental contamination by diesel exhaust fumes in railway tunnels, and the investigation of urban or industrial air pollution problems with the co-operation of provincial public health and municipal staff or industry. Air sampling stations maintained by such local and provincial staff are being co-ordinated into a national air sampling network, based on the employment of standardized sampling techniques, in order to correlate information obtained more readily with meteorological and other factors of the environment and to provide basic knowledge for research purposes.

For a number of years, staff of the Division, in co-operation with the Meteorological Branch of the Department of Transport, have been disseminating information to the International Joint

Commission and interested governmental and other agencies on the nature and frequency of temperature inversions from continuous measurements made on an 870-foot television tower in the Windsor-Detroit area. This project was originally designed to gather required data in connection with the Windsor-Detroit international air pollution reference. Recently, a 200-foot tower has been installed at the Central Experimental Farm, Ottawa, to aid in the study of community pollution problems and diffusion of pollutants as influenced by temperature, wind speed, turbulence and other factors.

In view of the importance of polycyclic hydrocarbons, especially those of known carcinogenic potency, in relation to lung cancer, a study is being made of the prevalence of such hydrocarbons in the filtered particulates of the urban environment, diesel and gasoline engine exhaust fumes. Methods of isolation and identification of these polynuclear aromatic hydrocarbons by column and paper chromatography, spectrophotometry and micro-chemical techniques are an essential part of this project.

Both the chemistry and physics sections of the Environmental Assessment Unit provide essential analytical services in the analysis of gaseous, liquid and aerosol contaminants, especially for provincial health departments. These services involve analytical and micro-chemistry, chromatography, electron microscopy and X-ray diffraction equipment and methods. Other activities of the Unit are more definitely related to the occupational health field.

The Biological Unit of the Occupational Health Division is concerned with investigations and research problems dealing with the biological effects and health aspects of the harmful substances to which man is exposed in his environment. Laboratory studies include the evaluation of the pathological and synergistic or potentiating effects of various mixtures of air pollutants on experimental animals; the changes in enzyme systems of such animals exposed to certain toxic chemical compounds in the body and the evaluation of the mechanism and rate of transfer of various chemicals across physiological membranes.

The Meteorological Branch of the Federal Department of Transport has recently established a research program in air pollution meteorology and allied fields at the Scarborough Field Station in Metropolitan Toronto. An investigation in fundamental aspects

of diffusion is being developed with appropriate instrumentation, including a collapsible, portable meteorological tower equipped with anemometers, bivanes and temperature instruments for determining lapse rates. Other activities of this group include research on ozone, radiosonde and solar radiation. Meteorological assistance is being provided to the Department of National Health and Welfare, Atomic Energy of Canada, the Department of Agriculture, the Ontario Research Foundation and the Ontario Air Pollution Control Branch.

In Canada, financial assistance in the form of federal health grants may be made available by the Department of National Health and Welfare to provincial health departments and through these provincial organizations to municipalities for air pollution research and field investigations, especially where health hazards are involved. This form of assistance is being utilized in various projects by the provinces of Nova Scotia, Quebec, Ontario, Manitoba and Alberta. A growing interest in this form of assistance is developing in New Brunswick, Saskatchewan and British Columbia. As provincial staff acquire training and experience under this program, the demands on the Department of National Health and Welfare for direct laboratory and field assistance in sampling and analysis of air contaminants will be expected to diminish and this will make it possible to devote more attention on the part of federal staff to problems of a fundamental nature.

Studies of air pollution involving international aspects between Canada and the United States are the responsibility of the International Joint Commission. Two problems of this nature have been investigated, as mentioned earlier, (a) the case involving damage to United States interests from operations of a smelter at Trail, B C., and (b) the control of air pollution from Great Lakes vessels plying the Detroit River.

Atomic Energy of Canada, with the assistance of the Meteorological Branch, is investigating various pollution problems connected with the safe dispersal and control of radioactive waste products discharged to the atmosphere from stacks of nuclear power plants. These studies include pre-operational surveys of the sites of the Nuclear Power Demonstration Plant, near Rolphston, and the vicinity of the proposed Canadian Deuterium Uranium Plant, near Kincardine, on Lake Huron.

Studies are in progress by various provincial health organizations, municipal and industrial organizations to evaluate the extent of air pollution from particulate and gaseous contaminants in a number of urban centers in Canada. These include Sydney, Montreal, Toronto, Hamilton, Sarnia, the Sudbury and Niagara Districts in Ontario, Winnipeg and Vancouver.

In the city of Sydney, Nova Scotia, the air pollution problem involves principally the extent of contamination of the city atmosphere by emissions from iron and steel manufacturing operations. This study involves a co-operative effort between the provincial department of health, municipal officers and the management of the Dominion Steel and Coal Corporation Limited, with some financial assistance under the federal health grants. The area affected by blast furnace and steel operations has been delineated accurately and appropriate control measures are being instituted.

A relatively unique form of group research has been in progress in the Sarnia area since 1952. The St. Clair River Research Committee, representing ten major industries, and the provincial government share the costs of a continuing air pollution research program. Field and laboratory research, since the inception of this study, has been carried out by the Ontario Research Foundation. The work has led to the voluntary introduction of control measures involving the expenditure of several millions of dollars by Sarnia oil refinery, chemical and petrochemical industries to lessen pollution in the area. A sporadic and troublesome problem has been the occasional occurrence of lachrymatory or irritating fumigations which may be analogous to the Los Angeles type of smog.

The Canadian Manufacturers' Association sponsored a three-year air pollution survey in Hamilton that commenced in October 1955. The cost of this study was borne entirely by approximately sixty Hamilton industries and the work was carried out by the Ontario Research Foundation. Not only were pollution levels measured throughout the urban area by means of a network of sampling stations, but major sources of emissions were pinpointed and an extensive stack sampling program was completed.

In 1958, Ontario became the first province in Canada to enact specific air pollution control legislation on a provincial level with the passage of Bill No. 152, known as The Air Pollution

Control Act. An Air Pollution Control Branch has been established under the Ontario Department of Health to administer the Act. This Act enables the Department of Health to engage consultants, make grants to universities for air pollution research, and assist municipalities in the preparation of air pollution control by-laws, in the development of air pollution control programs and in the training of local staff. The Branch may also furnish advice, initiate studies of air pollution problems and recommend standard procedures for air sampling and analysis.

Within the last two years, the Ontario Air Pollution Control Branch has carried out several interesting studies, including an assessment of air pollution levels, particularly with respect to sulphur dioxide, in a number of towns in the Sudbury nickel-copper smelting district and a unique study of vegetation damage from heavy metal dust, containing nickel, in Humberstone Township. Research is in progress on general particulate pollution levels and the extent of air contamination by aldehydes and other pollutants from vehicle traffic in Toronto.

Another Ontario Act entitled "The Damage by Fumes Arbitration Act" governs the emission of sulphur oxides from smelters roasting nickel, copper or iron ores in the province. This Act was passed in 1924 and has been revised on a number of occasions, the last time being in 1958. An arbitrator appointed by the Department of Mines is empowered to study and assess damage occasioned directly or indirectly to crops, trees or other vegetation by sulphur fumes arising from the smelting or roasting of the above ores or from the treatment of sulphides for the production of sulphur or sulphuric acid. A committee under this arbitrator has been investigating sulphur dioxide conditions and monitoring this gas at various sampling stations in the Sudbury District and elsewhere for a number of years.

The Industrial Hygiene Division of the Quebec Ministry of Health has recently initiated an air pollution study in the City of Montreal to assess major sources and the levels of airborne particulate matter, sulphur dioxide and hydrogen sulphide in relation to meteorological and other factors, following widespread complaints of odor episodes in various parts of the City. Systematic determinations of dustfall levels are being conducted throughout the Montreal area by the municipal Air Pollution Control Department. In Montreal East, a group of industries under the Laval Industrial

Association have organized a survey of air pollution levels in the area in relation to the voluntary control of industrial waste emissions from specific industrial operations.

The most comprehensive Canadian municipal organization for the study and control of urban air pollution problems is that represented by the Air Pollution Control Department of Metropolitan Toronto. An energetic effort is being made to control and abate such pollution as smoke, fly ash, dust and toxic gaseous emissions or odorous substances from fuel-burning equipment, power plants, incinerators, automobile traffic and diesel buses. Systematic observations are made of the concentrations of various pollutants as part of the overall effort to improve air quality in Toronto.

Observations of air pollution levels on a continuing basis are also being maintained by the municipal air pollution control organizations in Hamilton, Ontario, and Vancouver, B.C. An urban air pollution survey was initiated in Winnipeg in 1957 by the Bureau of Environmental Sanitation of the Manitoba Department of Health. This provincial bureau is also actively concerned with a variety of other problems related to the expanding industrialization of the province.

The growing industrialization of the Province of Alberta has created a number of air pollution problems. This province has become a major producer of oil and natural gas. Through the processing and purification of sour natural gas for transcontinental and export pipeline systems, large quantities of elemental sulphur and hydrocarbon by-products have become available for allied chemical industries. Currently, the Alberta Department of Health has under investigation a variety of problems involving emissions of hydrogen sulphide, sulphur dioxide, mercaptans and other odorous substances, waste chlorine from brine-caustic soda operations, and other effluents. An extensive study has been under way for several years by the Research Council of Alberta on the extent of contamination of air, water, vegetation and soils by fluorides released in the manufacture of phosphate fertilizer.

The British Columbia Research Council has been concerned for some years with research on methods of abatement of odors from effluents of kraft paper mills on Vancouver Island. This work has led to the design of an ingenious equipment system for the

oxidation of highly malodorous, uncondensable digester gases and conversion to less volatile products.

It is noteworthy that an increasing number of industrial companies are becoming aware of the importance of air pollution as a factor in existing and new manufacturing operations. This enlightened attitude on the part of management has resulted in the undertaking of air pollution surveys before and after the construction of their plants, in the assessment of sources of emission to abate or eliminate air pollution problems and in studies to determine the suitability of various sites from an air pollution control standpoint. The realization is growing that the capacity of the atmosphere to disperse pollutants to non-toxic proportions can be limited by topographical, meteorological and community development factors and that it is vital to preserve the purity of the air in the interests of good community relations, to safeguard health and prevent damage to agriculture, forests or property.

5. Control Legislation

(a) Federal Jurisdictional Aspects

Federal control of air pollution in Canada is restricted to activities concerned with navigation and shipping, public harbors, railways, public works, Crown companies and other subjects that are mentioned as coming under the legislative authority of the Parliament of Canada according to the distribution of legislative powers set forth in The British North America Act, 1867. Federal authority may also be invoked in situations arising out of industrial and other operations that result in the transboundary flow of air pollutants between Canada and the United States. Usually such international cases are referred to the International Joint Commission for study and settlement by arbitration.

The Railway Act has conferred on the Board of Transport Commissioners for Canada the authority to issue regulations for the control of air pollution from railway activities. A recent Order of this Board, issued as General Order No. 838 on April 1, 1959, replaced General Order No. 18 of 1909 and provided for the control of emissions of smoke from coal-fired steam locomotives, diesel locomotives, incinerators, other installations and open fires on railway property. These regulations apply to all railway companies subject to the jurisdiction of the Board, but they are applicable only in municipalities that have passed or may hereafter pass

by-laws for the regulation, control or prohibition of smoke or other air pollutants, and that have appointed or may hereafter appoint a municipal officer for control and enforcement purposes.

The federal government, through the Canada Shipping Act, exercises control of vessels and shipping activities on all navigable waters. Regulations governing the discharge of atmospheric pollutants from vessels may be provided by suitable amendments to this Act or by authorization under the Governor-in-Council, although such regulations have not been issued to date.

The International Joint Commission in its Report on the Pollution of the Atmosphere in the Detroit River Area, presented to the Governments of Canada and the United States on June 27, 1960, a number of recommendations with respect to the regulation and control of smoke from vessels operating on this international waterway. These recommendations are likely to have an important bearing on future action to control air pollution from shipping in harbors and navigable waters of the Great Lakes and St. Lawrence Seaway System.

(b) Provincial Jurisdictional Aspects

Except for the cases cited above, the regulation and control of sources of air pollution from varied activities of industry and commerce is the main responsibility of the provincial governments. These authorities may delegate certain powers or provide for enabling legislation whereby municipalities or incorporated local governments may pass by-laws to prohibit or restrict the emission of smoke and other products of combustion from sources within their boundaries.

In March, 1955, the Ontario Government appointed a Select Committee on Air Pollution to examine existing legislation and practice in relation to smoke control and air pollution with particular reference to the installation and maintenance of equipment for control purposes and methods of extending public information in connection with the problem. This Committee visited 42 municipalities of which 28 were located in Ontario and heard evidence from several hundred witnesses. A final report containing the findings and recommendations was presented to the provincial legislature during the 1957 session [15]. The Air Pollution Control Act, 1958, came into force in Ontario on May 21, 1958 and sections of the province's Municipal Act dealing with air pollution were repealed.

The 1958 Act (as amended in 1959 for purposes of clarification and ease of administration) delegates broad powers to municipalities to prohibit or regulate emissions from any source.

Under the above Act, an Air Pollution Control Branch has been established within the Ontario Department of Health to furnish advice in the field of air pollution, to assist municipal officials in preparing air pollution control by-laws, in developing air pollution control programs, and in training local staffs for this purpose. Authorization is given to investigate or make arrangements for investigation of air pollution problems.

The council of any municipality may pass by-laws for prohibiting or regulating the emission from any source of air contaminants or any type or class thereof, under Section 3 of the Act.

The Ontario Act provides that a proposed by-law under Section 3 shall be submitted to the Minister of Health for review and advice during a thirty-day period prior to passage. Section 5 provides that any two or more municipalities may enter into agreement to provide for joint administration and enforcement of their respective air pollution control by-laws and to provide for the sharing of the cost thereof.

Under Section 6 of the Act, the Minister may, with the approval of the Lieutenant-Governor in Council, make regulations for prohibition or control of emission of air contaminants from any source, applicable in territory without municipal organization. Such regulation may be general in its application or may be restricted to any designated, specific area or class of premises.

One further legal device available to the Province of Ontario may be mentioned. Under the Sulphur Fume Damage Arbitration Act, an arbitrator, acting under the Ontario Department of Mines, may appraise damages and assess penalties in such cases as injury to agricultural and forest species by sulphur fumes from smelting or refining of nickel, copper, or iron ores.

A special arbitration act passed by the Manitoba Government in 1957 deals with the emissions of waste products from the Manitoba mining and smelting industry.

In 1960, the Province of Manitoba passed a new regulation dealing with atmospheric pollution as an amendment under The Public Health Act. This regulation declares that it shall be unlawful and a nuisance for any person to cause, suffer or permit smoke, dust, cinders, fly ash, fumes or gases, or offensive odors to discharge or escape from any building or premises to the detriment or annoyance of others.

In Alberta, the Department of Public Health has assumed direct responsibility for the regulation and control of atmospheric pollution from industrial sources. Plans and specifications for all types of new plants that may discharge contaminants to the air must be submitted to this above Department for approval as to location of site and the remedial measures contemplated to abate or eliminate harmful or odorous waste products. Some of the major problems are concerned with the rapid expansion of natural gas processing and elemental sulphur recovery plants. These plants vary in size according to the quantity of sour gas to be processed and the hydrogen sulphide content of the raw gas; with the smallest installations being of the order of 20 to 100 tons of sulphur per day and the larger ones, 500 to 900 tons per day. Some larger units are expected to be built in the future. It is an essential requirement that all sulphur compounds and waste gases from such plants, that cannot be recovered economically, should be incinerated prior to venting to the atmosphere through tall, properly designed stacks. Estimates of potential annual production of sulphur in Alberta indicate a level of about 3 million tons per annum in three to five years.

The Division of Sanitary Engineering of the Alberta Department of Public Health has been engaged in the study of various air pollution problems since 1957, with gradual expansion of staff and facilities, in order to recommend control measures and formulate desirable policies. Studies of urban air pollution and control programs have also been initiated by this Division in the cities of Edmonton and Calgary. It is anticipated that Alberta will introduce specific air pollution control legislation in the near future in view of these activities and the rapid growth of industry.

In Quebec, keen interest in the study and control of atmospheric pollution problems has been shown by the Division of Industrial Hygiene of the Quebec Ministry of Health. Although

there is no provincial act directed specifically towards the regulation and control of emissions, complaints of odor nuisances and conditions that may represent a hazard to health or are likely to damage vegetation and property are investigated with a view to remedial action. Technical assistance may be rendered to municipalities upon request but it is a matter of policy to leave the control of smoke and air contaminants from fuel-burning equipment, incinerators, etc., in urban areas, under local jurisdiction.

In other provinces of Canada, the control of pollution is left largely at the local level. There are no provincial acts directed specifically to air pollution control. Such powers as may be delegated to municipalities are derived either under provincial health or municipal acts.

(c) Municipal Jurisdiction Aspects

Such organizations as the U.S. Bureau of Mines, the American Society of Mechanical Engineers, the Air Pollution Control Association (Pittsburgh), and the Los Angeles County Air Pollution Control District have had marked influence on the nature of municipal control regulations and the extent to which various contaminants from vents or stacks such as smoke, dust or fly-ash, sulphur dioxide and other types of emissions may be prohibited or controlled.

For example, regulations passed in May 1957 by the Municipality of Metropolitan Toronto prohibit the discharge to the atmosphere of smoke, dust, fly-ash, soot, fumes or other solid or gaseous products of combustion, the shade or appearance of which is equal to or greater than No. 2 on the Ringelmann Smoke Chart, for a period of or periods aggregating ten minutes or more in any one hour. It is also prohibited to discharge such contaminants at a density equivalent in shade or appearance to, or greater than, No.3 Ringelmann for a period or periods aggregating six minutes in any one hour. Further, no person shall cause, suffer or allow to be discharged from any fuel-burning equipment, internal combustion engine or vehicle, or from any premises such contaminants, as mentioned above, to an extent that is detrimental to the property of any other person or that is a nuisance to any person.

The Metropolitan Toronto by-law contains clauses relating to a requirement for increasing the height of existing stacks and chimneys to abate a nuisance to occupants of any building or structure subsequently erected. There are also included in this by-law

the customary provisions for the issuance of installation and operating permits for fuel-burning equipment, inspection of premises and equipment, investigation of complaints and study of smoke conditions.

The regulations of most other cities and towns in Ontario that have passed by-laws to control air pollution contain similar features to those of Toronto, except for minor modifications. Since proposed new by-laws to control air pollution have to be submitted to the Ontario Minister of Health for review and advice, prior to adoption, in order to insure conformity with the Provincial Air Pollution Control Act, 1958, it is anticipated that municipal regulations will become uniform in nature in the future.

The Township of Trafalgar, Ontario, has enacted air pollution control regulations directed specifically toward oil refining operations located within the township. These contain some unique features as influenced by the provisions of regulations in the by-laws of the Los Angeles Air Pollution Control District. In addition to the usual prohibitions against emission of excessive smoke from furnaces, flares and combustion equipment, the Trafalgar by-law limits the discharge of dust from a catalytic cracking unit, based on the handling of 7,000 barrels of feed intake per day, to an average of 30 tons per month or one ton per day (about 83 lbs. per hour). The emission of sulphur dioxide from any process unit stack is restricted by the maximum ground concentration which must not exceed a top limit of 0.5 parts per million in air, by volume. To meet this limitation on the discharge of sulphur dioxide, it is evident that stacks, chimneys, or flares, handling products of combustion that contain major amounts of sulphur dioxide, must be adequately designed to provide sufficient height to disperse effectively the waste gas under a wide variety of meteorological conditions.

Other clauses in the Trafalgar by-law provide for the installation of conservation or floating roofs on oil storage tanks, for covering API oil-water separators up to the first oil retention baffle, and for the suppression of vapor losses generally from pressure relief vents, valves, product storage tanks, loading and filling operations. Here, again, the insertion of these clauses in the by-law has been based on the experience and reports of the Los Angeles Air Pollution Control District.

(d) Trends in Control Regulations

In view of the intensive study and publicity that has been given to the troublesome Los Angeles air pollution problem, the regulations enacted in Los Angeless County, although designed to deal with the local situation, are likely to influence future control activities in many other areas of North America. However, few if any other industrial areas in the world have to contend with the unfavorable meteorological and topographical factors that produce the prolonged temperature inversions and smog of the Los Angeles type.

In Canada, air pollution control regulations and standards of emission may become more stringent in the future but are not likely to approach the relatively severe limitations imposed in the Los Angeles area. In the case of smoke emission from fuel-burning equipment, most of the municipal ordinances prohibit the discharge of No. 2 smoke or darker shade on the Ringelmann chart, except for specified, limited periods in any one hour or fraction thereof. The emission of other visible contaminants, apart from smoke, may be regulated by an opacity clause which is equivalent to the obscuration of an observer's view of the stack discharge to an extent equal to No. 2 Ringelmann. This may cover the emission of sulphur trioxide or sulphuric acid mist, oxides of nitrogen, and other products of combustion or chemical fumes, mists or gases.

Thus far, there are only two areas in Canada where statutory limitations have been imposed directly on the discharge of sulphur dioxide. These limitations involve in one case a decision of the Trail Smelter Arbitral Tribunal between Canada and the United States which prohibits the smelter at Trail, B.C. from discharging sulphur dioxide in any amount that may result in a maximum ground concentration that exceeds 0.30 p.p.m. during the growing season, or 0.50 p.p.m. during the non-growing season, for a period greater than about one hour, at any point beyond the international boundary in United States territory. The second case is that of sulphur dioxide from oil refining process units in the Township of Trafalgar, Ontario, under By-Law No. 1957-50, mentioned previously.

With reference to the regulation of the emission of dust or fly-ash from fuel-burning equipment, the trend is to adopt the relevant clause in the model ordinance of the American Society of Mechanical Engineers which provides that the dust loading of stack gases shall not exceed 0.85 lb. dust or fly-ash per 1,000 lb. of

gases adjusted to 50 per cent excess air (or 12 per cent CO_2 content). To this may be added a stipulation that would prohibit the emission from a stack of more than 15 per cent of the total dust measured at the point of entry to a collection device. The 15 per cent restriction on dust emission makes an ordinance of this type more severe than the ASME model, since, in some cases, the dust loading in the stack may have to be reduced below the 0.85 lb. per 1000 lb. limit to comply with this other provision.

The above restrictions on dust or fly-ash discharged to the atmosphere along with smoke emission limitations tend to make it more difficult to utilize bituminous coal as fuel, especially when it contains upwards of 8 to 12 per cent of ash. Additional control facilities are required to handle solid fuel consumption, especially in the range of 1,000 to 5,000 tons or more per day in large installations for industrial steam plants or for generation of electric power. The dust collection or precipitation equipment to recover and dispose of the resultant fly-ash adds to the capital cost of construction of steam plants utilizing pulverized coal in contrast to relatively "smokeless" fuels such as oil or natural gas, which can meet air pollution control regulations without the necessity for installation of dust recovery systems.

Rapid progress is being made in the dieselization of the railway systems of Canada. Eventually, coal-burning locomotives will be replaced entirely by diesel locomotives in freight, passenger and yard switching operations. The Board of Transport Commissioners for Canada in the new General Order No. 838, dated 2 February, 1959, specify that it is not permissible to discharge smoke of a density greater than No. 2 of the Ringelmann Chart from coal-burning locomotives in service or ready for service, except that a density equal to but not greater than No. 3 will be allowed for a period or periods aggregating not more than 90 seconds in any single 10-minute period. In the case of oil-fired diesel locomotives the restriction on smoke emission is more severe and the limitations are No. 1 and No.2 for comparable locomotive operations. Other clauses in the order contain prohibitions on smoke emission of specified densities from other railway equipment, internal combustion engines, locomotive repair shops, incinerators and other property.

The trend toward oil-burning and diesel equipment in place of coal-fired furnaces is also evident in vessel transportation on the

Great Lakes and St. Lawrence Seaway system. Studies of the Technical Advisory Board on Air Pollution for the International Joint Commission show that hand-fired, coal-burning vessels contribute seriously to the pollution problem in the Detroit River Area as it is not possible to meet the requirements of modern smoke abatement codes with such equipment. The most satisfactory performance in the control of smoke is shown by vessels equipped with diesel engines, followed in second place by vessels with oil-fired furnaces. Vessels containing automatic, stoker-fired furnaces for handling solid fuel rank third in smoke control performance.

6. Standards for Ambient Air Quality

There is insufficient knowledge at present on the effects of community air pollutants on vegetation, property or health to enable the establishment of broad air quality standards that would specify the limits of allowable concentrations for a wide range of compounds. However, some progress in this direction has been initiated by the California State Department of Public Health in accordance with additions to the Health and Safety Code enacted by the California Legislature in 1959. Certain limited standards for ambient air and motor vehicle exhaust were adopted on December 4, 1959, after a study of the effects of a number of air pollutants from published scientific data and evidence presented at public hearings[16]. In developing these standards the Department obtained the advice of scientists with recognized competence in their fields. It is planned to re-evaluate, modify or expand the list of standards from time to time as reliable scientific data permit.

Three levels of air pollutants were defined in the establishment of a graded set of standards, as the toxic effects vary both in character and in severity. These levels are as follows:

(1) "Adverse" Level

The first effects of air pollutants are those likely to lead to untoward symptoms or discomfort. Though not known to be associated with the development of disease, even in sensitive groups, such effects are capable of distrubing the population stability of residential or work communities. The "adverse" level is one at which eye irritation occurs. Also in this category are levels of pollutants that lead to costly and undesirable effects other than those on humans. These include damage to vegetation, reduction in visibility, or property damage of sufficient magnitude to constitute a

significant economic or social burden.

(2) "Serious" Level
Levels of pollutants, or possible combination of pollutants, likely to lead to insidious or chronic disease or to significant alteration of important physiological function in a sensitive group, define the "serious" level. Such an impairment of function implies a health risk for persons constituting such a sensitive group, but not necessarily for persons in good health.

(3) "Emergency" Level
Levels of pollutants, or combination of pollutants, and meteorological factors likely to lead to acute sickness or death for a sensitive group of people, define the "emergency" level.

Motor Vehicle Exhaust Emissions
The exhaust gas from motor vehicles is a major source of air pollution in the larger metropolitan districts or conurbations. It is recognized by competent authorities that a substantial reduction in the quantities of hydrocarbons, oxides of nitrogen and other exhaust contaminants represents one of the most important measures in the control of photochemical smog and carbon monoxide pollution. The link between motor vehicle exhaust and the formation of photochemical smog rests upon experimental evidence from California scientists that effects typical of Los Angeles smog are produced by the solar irradiation of mixtures of certain organic compounds and nitrogen oxides. The olefins, as a group, are the most reactive of the organic compounds.

In December 1959, the State of California adopted standards of emissions for some motor vehicle exhaust contaminants[16]. It was assumed, in the determination of the degree of exhaust control required, that the concentrations of typical phytotoxic substances, eye irritants and photochemical aerosols are related directly to the concentration of olefins in polluted atmospheres. Nitrogen oxides are also essential to the photochemical reaction and contribute markedly to the photochemical formation of ozone. However, the air quality standards do not include ozone, as yet. A substantial reduction in the current ozone levels of certain California communities would require curtailment of the quantities of oxides of nitrogen that are normally present in motor vehicle exhausts. Technically, there is no suitable equipment available at present to

to achieve this purpose.

The California standards for motor vehicle exhaust are as follows:

> Hydrocarbons - 275 parts per million by volume, estimated as hexane
> Carbon Monoxide - 1.5 per cent by volume.

Methods of measurement and analysis of a composite sample of exhaust gas representing the prescribed driving cycle are described in the above mentioned State of California publication. It is anticipated that the necessary equipment in the form of exhaust "afterburners" or catalytic combustion devices will be made available by the automobile manufacturing industry to enable the state to enforce these standards on all new vehicles operating in California in the near future. The application of the above standards to all motor vehicles of the state is expected to reduce the emission of hydrocarbons from this major source by about 80 per cent and carbon monoxide by 60 per cent.

7. Technology of Prevention and Control

A large amount of engineering and scientific information has become available on processes and equipment for the abatement and control of sources of air pollution related to specific contaminants. However, in the present state of our knowledge, the complete removal or elimination of pollution from many types of sources is not practicable on economic grounds. In other cases, problems of control involve difficulties that can only be solved by more fundamental and applied research. Excellent reviews of this subject have been presented in the Air Pollution Handbook[17] and in a recent monograph on Air Pollution published by the World Health Organization[18].

Many factors enter into the degree of control necessary to prevent or overcome air pollution in a specific area. These include the mass rate of emission of contaminants to the atmosphere, the nature and concentration of particular sources, the meteorological and topographical characteristics of the area, susceptibility of the area to air pollution, and proximity of major sources to residential, agricultural, recreational and other land uses. Sources of emission vary considerably in the quantities of contaminants discharged to the atmosphere in terms of weight loss per unit of fuel used or

materials processed. For example, typical loss rates for some classes of industrial and transportation sources are as follows[18]:

	Loss Rate by Weight of Fuel or Material Processed
Combustion processes	0.05% - 1.5%
Automotive engines	4% - 7%
Petroleum operations	0.25% - 1.5%
Chemical processes	0.5% - 2%
Pyro- and electro-metallurgical processes	0.5% - 2%
Mineral processing	1% - 3%
Food and feed manufacturing	0.25% - 1%

There are four basic procedures available for the control of emissions to the atmosphere and abatement of injurious or detrimental consequences.

(1) The use of control or recovery equipment to reduce or prevent the discharge of contaminants at the source.

(2) The introduction of changes in raw materials, operational practices or procedures, or modifications, including replacement of process equipment to reduce emissions.

(3) The erection of tall stacks to assist the diffusion and dispersion of contaminants.

(4) The application of principles involving zoning, site selection and community planning to the distribution of industrial locations in relation to land usage.

Equipment for air pollution control is utilized to prevent the creation of a nuisance or damage to property or vegetation, to

eliminate hazards to health and safety, and to reduce economic losses in production and plant maintenance through the recovery of valuable by-products, improvement in product quality and in rate of deterioration of plant equipment. There are two basic types of control equipment utilized for this purpose - installations to remove emissions of solid and liquid particulate matter or aerosols and equipment to reduce the discharge of gases.

The performance of air pollution control equipment is expressed usually in terms of collection efficiencies. In the case of dust or aerosol collection equipment, the efficiency may be defined as the percentage of material removed by weight, percentage removal by weight over a range of particle sizes, or percentage removal by number of particles in unit volume of stack gas. The effectiveness of smoke or dust control equipment may also be assessed by measurement of the relative opacity of the discharge before and after passage through the collection apparatus by optical methods. The efficiency of control equipment for gases is expressed in terms of the concentrations of the contaminating gaseous material before and after passage through the equipment and release to the atmosphere.

8. Planning and Zoning to Control Air Pollution

The problem of town planning and zoning in relation to the location of industrial areas and control of air pollution has been discussed by Katz in the Air Pollution Handbook[19] and by Taylor, Hasegawa and Chambers in the W.H.O. Monograph on Air Pollution[20]. Today, the regulation and control of air pollution is a recognized practice in many urban areas. The introduction of efficient methods of combustion and gas cleaning equipment for the collection of dust or scrubbers for the removal gases has reduced pollution levels but this trend has been offset by population growth and the continued expansion of industrial and public activities. There are only two possible ways in which atmospheric waste products can be controlled - (1) by collection or removal at the source, (2) by dilution and dispersion in space and time. Most authorities will agree that it is theoretically possible to remove nearly all objectionable particulate and gaseous effluents from industrial stacks but the attainment of this objective may be unrealistic on economic grounds. Costs of recovery and disposal of waste products rise rapidly at higher efficiencies and may become prohibitive beyond 95 per cent removal. Intelligent planning and zoning of land use, therefore,

must be undertaken in order to maintain the balance between industrial expansion, opportunities for employment and the prevention of adverse levels of pollution that might create corrosion, nuisance, crop damage or health problems.

(a) Basic Considerations
Some conception of the basic requirements for sound city planning and zoning may be gained by a glance at conditions which arise in the absence of any plan or design for community development. Small businesses and industries invade residential areas; these begin to deteriorate, lose property values, and decay. The expansion of industrial plants into areas settled by workers eventually drives these workers to seek living accommodation in other sections of town many miles from their work. On the other hand, homes may grow up inside factory districts. Instead of compactly organized neighborhoods with appropriate business and shopping centers, ribbon streets or narrow, intermixed communities may stretch out for miles. Uncontrolled smoke, dust, fumes, and odors accelerate the deterioration of such haphazard and disorderly developments and create blighted areas.

It is almost an axiom, therefore, that city planning must be continuous, flexible, and adapted to the local requirements. It must be based on correct and sufficient data to anticipate the growth trends and changes in living habits which the city will undergo in the near future. Provision must be made for transportation, traffic and parking facilities as well as accommodation for industry, commerce, homes, and apartments, so that the city can grow without sections being blighted and ultimately having to be reconstructed at enormous cost to the taxpayer.

To implement a plan conceived by a competent commission or authority, a zoning law is required to define the permissible areas for all functions of the community, such as light and heavy industry, business or commerce, parks and playgrounds, warehouses, office buildings, apartments and dwellings. Many cities with good zoning regulations have nullified them by granting exemptions whenever sufficient pressure has been applied to permit land use not in conformity with the regulations. Each city requires its own zoning ordinance, and it must fit the local conditions. As land usage changes, the zoning regulations must be modified to meet new conditions. Rural or suburban areas bordering a city must also be subjected to zoning to promote orderly growth.

The effects of air pollution on future zoning are being taken into consideration by some city-planning commissions. Thus, proposals are under study to zone industry on the basis of the nature and extent of the emission from each plant rather than by the type of manufacturing process or operation. This provides an incentive for improved pollution control in the design of a new plant, because a more desirable site may be available if the plant can meet the stack-emission and other requirements in the preferred zone. As more information is gained about the effects of specific contaminants and the levels of ground concentration which may be permissible with respect to each type of waste product, zoning ordinances will contain performance provisions on specified permissible contamination limits rather than indefinite terms such as "detrimental, noxious, or offensive." The regulations would be more helpful to industry if positive performance standards for various classes of operations were required instead of being expressed in terms of what may not be done. However, the drafting of such performance zoning regulations requires a high order of technical skill and knowledge on the part of air pollution control agencies or planning bodies. At present, factors such as stack height, velocity and temperature of stack gases, wind velocity, and prevailing meteorological conditions in a given neighborhood are neglected in the setting up of control regulations based on permissible stack concentrations or, as in Los Angeles County, emission standards are based on process weight per hour (mass rate of emission).

With the continued growth of cities and industrial communities, air pollution control is assuming increasing importance in planning and zoning. Meteorological and topographical factors must be taken into account in the location of industrial and residential areas. It is essential to protect industry from the unreasonable encroachment of residential developments, and vice versa. In future planning and zoning, land use for certain types of industrial operations will depend on the extent to which such plants can control objectionable contamination. Area zoning will include more extended use of land for public parks, gardens, and wooded tracts to prevent over crowding of sources of emission.

(b) Air Pollution Parameters for Zoning

Munn[21] has discussed, recently, the application of certain meteorological concepts to town planning that take into consideration the air pollution climatology of an area. He has listed the following

factors that must be considered in order to reach the best decision on air zoning.

(1) Air pollution climatology. The usual data available from weather stations on wind speed, direction and frequency distribution, temperature, precipitation, sunshine, etc., should be supplemented by some knowledge of frequency, thickness and persistence of inversions.

(2) Allowable threshold limits of concentrations of various gases and particulates. Although there is no agreement by competent medical and other authorities on the effects of prolonged exposure to the relatively low concentrations of contaminants that are usually found in urban atmospheres, an increasing fund of knowledge is being developed on desirable criteria for air quality standards. The objectives of town planning must be clearly stated with respect to the degree of protection that is desired in relation to health or prevention of property damage.

(3) Population density distribution. This factor assumes special significance in site selection for certain types of heavy industry, sources that may emit, accidentally, highly toxic or malodorous substances, or for nuclear power plants.

(4) Existing pattern of pollution levels. A knowledge of the existing distribution pattern of air pollution concentrations at ground level is necessary in order to be able to evaluate the influence of new sources of emission. For example, Frenkiel in 1956[22] predicted the mean hourly concentrations of certain contaminants at a particular sampling station in Los Angeles for the year 1980, on the assumption that there would be no change in efficiency of abatement methods as prescribed by the L.A. Air Pollution Control Department and assuming an orderly growth of population and industry. This type of approach deserves careful consideration from the standpoint of long-term city planning.

(5) Land utilization in relation to air zoning. Land usage on a regional basis for industrial purposes is governed normally by such factors as availability of markets, labor, raw materials, transportation costs, water supply, power costs, living conditions and climate. Local site selection factors include availability of usable land, building costs, proximity to transportation, housing and labor;

the presence of utilities and related industries; facilities available for plant protection, housing and recreation; regulations as to pollution of water and air and zoning restrictions. Since air zoning is only one factor in the utilization of land for town planning purposes, it is usually considered in the light of factors mentioned above. However, cases will arise where the air pollution potential of an industry may become the dominant factor governing selection of a suitable site.

It is beyond the scope of this paper to discuss all the meteorological and physical factors involved in the dilution and diffusion of gases and aerosols in relation to site selection in order to minimize air pollution hazards. Much information on this subject is available in the Air Pollution Handbook. Munn[21] has discussed seven mechanisms of the diffusion process that can produce unduly high surface gas concentrations or particulate depositions and has also given examples of some simple applications of meteorological design criteria for the evaluation of sites in a metropolitan area to yield the least amount of air pollution.

(c) Industrial Site Selection and Zoning

In planning the location of an industrial plant, the factor of air pollution control must be included in the basic considerations which have to be assessed by modern plant management. No longer is it sufficient to consider only the availability of raw materials, labor force, transportation, water supplies, and markets. Past neglect of air pollution planning has proved to be a costly error for many large undertakings which have been faced with expensive damage claims, litigation, and the necessity for the installation of control equipment after several years' operation. It is usually much simpler and less expensive to provide for control features in the design stage than to be compelled to add these after the plant has been constructed and placed in operation.

If the new plant is to be located in an area which is already industrialized, it is sound practice to undertake a preoperational survey to determine the existing levels of contaminants under prevailing meteorological conditions. The results of such a survey, in conjunction with known operational data on the scale of contemplated emissions from the new sources, would provide information on the extent to which waste products could be safely discharged to the atmosphere without producing too much contamination. An intelligent

appraisal of the problem requires a knowledge of the specific effects of the major contaminants to be discharged to the atmosphere in relation to the topography, population, and land use of the area surrounding the site. Certain contaminants are more toxic to vegetation and animals than to people. A rural and agricultural area is more sensitive to sulphur dioxide and fluorides than is an urban community. Hydrogen sulfide has little effect on vegetation but is obnoxious and even dangerous to human life in comparatively low concentrations.

A preliminary air pollution survey is also useful if the site to be selected is located in a suburban or rural area. Frequently, the area under consideration is subjected to exotic pollution, i.e., contamination from distant sources. It is important to establish what these concentration levels may be in relation to the proposed scale of operations. Suspended particulates, fluorides, sulphur dioxide, and other gases may be carried great distances from large industrial communities to predominantly rural areas. The existing conditions may be tolerated by the rural dwellers until a new plant commences activities in the immediate neighborhood.

The ideal site for disposal of airborne wastes is comparatively level terrain in a region where the average wind velocity is of the order of 10 mph or more and where deep temperature inversions are a rare occurrence. An additional advantage is gained if the site is not upwind of valuable farm land or a populated community. The plant-site property should be large enough so that maximum concentrations of effluents, at ground level downwind, occur well within company premises rather than on surrounding private property. Valley sites require more pollution control than level or undulating terrain, especially when the average wind speed is less than 10 mph. Stacks must be tall enough so that the effective height of the plume will permit atmospheric wastes to be carried out of the valley rather than to be trapped below the level of the surrounding hills.

A large power plant burning 5,000 to 10,000 tons of pulverized fuel per day may discharge 300 to 600 tons of sulphur dioxide daily and a large amount of fly ash if the coal contains about 3 per cent sulphur. With the removal of fly ash by the operation of electrostatic precipitators or other dust collectors of 95 per cent efficiency, the plant may still release upward of 25 to 50 tons of

ash per day. About 30 per cent of this ash may be deposited in the neighborhood of the plant. If the effective discharge height is 400 ft., most of this deposition will occur within about 1,600 to 4,000 ft. of the plant in a wind of 10 mph. Let us suppose that 75 per cent of the dust is deposited within a radius of one mile. The monthly dustfall rate over this area of about three sq. miles will then be approximately 54 to 108 tons/sq. mile. The sector in the prevailing wind direction will have a greater rate of deposition, and other sectors will be correspondingly lower, depending upon the frequency distribution of wind direction. Proper zoning of an operation of this magnitude would require that the industrial site be located on about 2,500 to 5,000 acres in order to minimize the hazard from both dust and sulphur dioxide damage on adjacent property. Under favorable conditions of topography and micrometeorology, the effective dispersion of such a large amount of waste sulphur dioxide would require stacks 400 to 600 ft. tall.

Modern control measures for smelters and steel, aluminum, and other large plants include not only the recovery of a substantial portion of the waste sulphur, fluorides, and dust from metallurgical operations, but also the ownership of sufficient land to prevent the occurrence of excessive ground concentrations or damage to valuable farm or forest property. Such land ownership provides a method of industrial zoning by private management. This pattern can be assisted greatly by municipal or county planning for industrial-plant location. This involves zoning restrictions so planned that residential areas and certain heavy industries will not be located too close to each other. Although the location of new industries will result inevitably in the growth of new communities or the expansion of existing towns, such growth could be planned and zoned to prevent the encroachment of residences in the immediate vicinity of factories, especially in the prevailing downwind direction.

Certain chemical plants may discharge vapors and gases which react in low concentrations in the atmosphere to produce eye-irritating and other unpleasant effects by direct or photochemical reactions. Thus a synthetic-rubber plant, producing or utilizing butadiene and styrene, located adjacent to a chlorine or hydrochloric acid plant, may create a pollution problem as a result of joint operations where none would exist if these plants were situated at a reasonable distance from each other. Halogen compounds and unsaturated cyclic hydrocarbons, such as styrene, can react in

extremely low concentrations in the air in sunlight to produce lachrymators. Other irritating or phytotoxic substances may be produced photochemically by the interaction of atmospheric waste products consisting of hydrocarbons and oxides of nitrogen under the influence of sunlight. Such conditions provide an additional incentive for industrial zoning to prevent the haphazard location of industrial plants and to segregate certain types of industries.

In the zoning of land for industrial use it is apparent that due consideration must be given to all factors which govern the diffusion and dispersion of atmospheric contaminants, including topography of the area, frequency and speed of prevailing winds, and stability of the air.

(d) Planning for the Future

Many cities are now paying the price of past failure to plan for future orderly development. Smoke, dust, odors, and poor zoning practices have destroyed fine residential sections and created blighted areas in the central parts of some cities. The resultant unattractive living and business conditions tend to drive people away to the suburbs. The deterioration in property values soon makes it uneconomic to maintain buildings in good repair or to modernize them, and the whole neighborhood degenerates into a slum area. The newer built-up sections undergo the same process of decay in time as factories and other business enterprises creep into locations where they are not desirable.

There can be no successful solution to the problem of eliminating blighted areas in our large cities until air pollution is properly controlled. However, in many instances intelligent zoning and air pollution control measures must be carried out on a regional rather than a local basis. This requires co-operation between counties and states or provinces as well as between adjoining municipalities. Thus in the Philadelphia and Delaware River Valley industrial area, there is a tristate situation with regard to pollution control involving Pennsylvania, New Jersey, and Delaware. A similar situation exists with respect to large cities and factories bordering New York and New Jersey and along some points of the international boundary between Canada and the United States.

Extensive reconstruction and development programs have been undertaken by a number of large cities of North America within

the last few years to remove blighted areas, plan for future orderly growth, and make living more attractive within city limits. This involves the expenditure of large amounts of money from both public and private sources for slum clearance, housing developments, transportation facilities, and air pollution control equipment. Successful results are being achieved by this process of planning and rebuilding, especially with the co-operation of community leaders representing industry, labor, and public-spirited bodies.

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THE IMPACT OF URBAN GROWTH ON AGRICULTURAL LAND: A PILOT STUDY:

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Elements of the Study

The Main Question

In the past year there have been three reports concerned with our resources and our environment that have made reference to the impact of urban growth on agricultural land. The report of The Royal Architectural Institute of Canada on The Design of The Residential Environment raises two questions, first:"To turn farmland to city land is an almost irrevocable step; looking at this land as a non-renewable resource, how fast are we using it up to make cities?" secondly: "The national economy must gain in the long run if we can make as much useful city accommodation, without using land so fast; can we?"[1] A Report on Land Use By the Conservation Council of Ontario has dealt with the second question by examining the research evidence for one region - the Niagara Peninsula, and concludes that "there is ample room for all of the additional urban population forecast for the future; that given care, fruit production can continue at the same level despite urban development, provided there is proper protection of remaining high quality lands".[2]

The first question - at what rate do we use up farmland as cities grow? - was taken up in earnest by A.D. Crerar, Research Planner, Lower Mainland Regional Planning Board, in a brief prepared for the "Resources for Tomorrow" Conference on behalf of the Community Planning Association of Canada. This study on The Loss of Farmland in the Growth of the Metropolitan Regions of Canada, based on Census information on the amount of farmland around urban centers in 1951 and 1956, concluded that for metropolitan areas located in areas of fair to good agricultural

capabilities, there was an average loss of farmland of 382 acres for each 1000 increase in population. The author observes that if the use of land for actual development purposes conforms to the Vancouver standard of 108 acres per 1000 population increase, it can be further concluded that the cities can be considered "to be wasting 2.54 acres for each one that they consume".[3] But this is a statistical deduction and the question of how much of the farmland loss was "wasted" - i.e. not actually needed for development - remained an unresolved question.

Purpose, Scope and Location

This report takes up, in a small way, the task of examining the facts in a number of selected areas on the direct and indirect impact of urban development on agricultural land. From primary sources, the study aims to determine the quantity, location and quality of land consumed directly for development, and affected indirectly - in the sense of being taken out of or gradually pressured out of agricultural production.

For the purposes of this study, "urban development" includes the following uses of land:

1. Housing, including permanent country residences.

2. Industry, including manufacturing and warehouses.

3. Commercial districts, including retail, wholesale and office functions.

4. Recreation facilities, serving the urban population.

5. Highway services related to the city (e.g. motels, service stations, etc.)

6. Transportation facilities - airports, trucks terminals, railway stations and related facilities.

7. Utilities, e.g. water treatment and sewage disposal plants.

8. All roads, and railway lines, and off-street parking facilities within the limits of the foregoing uses (1 to 7).

Four indicators of land indirectly affected by urban development are used in this study:

1. Undeveloped subdivisions, i.e. land subdivided for urban purposes but undeveloped.

2. Non-farm ownerships of farmland, i.e. land owned by other than a farmer or other rural user of land (e.g. by an urban interest).

3. Farmland for sale for urban purposes.

4. Non-farm assessment, i.e. land used for farming, assessed at levels higher than the normal rural levels for such purposes.

The area defined by these factors identifies the limits of "urban shadow" - the area of surrounding farmland which, because of the influence of the town, is to all intents and purposes sterilized for agricultural purposes; or subject to pressure pushing it out of agricultural production.

The communities selected for analysis in the foregoing terms are Lindsay, Stratford, Kingston and London*. They were selected with a view to observing the differences in both direct and indirect effects on land of urban communities of different size. The four communities approximate a representative cross-section by size of Ontario communities - ranging from the rural service center, Lindsay, with a population in 1960 of about 12,500; through the larger regional centers of Stratford, with 22,000 and Kingston, with 61,000; to the metropolitan center of London, with a population, in 1960, of 175,000. These population figures include, in each region, the people living in outlying settlements, towns and villages who work in the major urban center.

The definition of the study region in each case is determined by the four factors selected to define the area of "urban shadow". Thus, the defining factors are uniform but the actual geographical scope of the study varies with the size and type of center, as may be seen from the maps that accompany this text.

Direct development effects are determined by comparing urban development in January, 1951 with new urban development in

* See maps of these communities following page 179

the ten-year period between January 1, 1951 to December 31, 1960, and indirect effects are determined by comparing urban development in 1960 with urban shadow on December 31, 1960.

Specifically, the results of the study are summarized in the following statistical statements for each of the four centers:

1. Urban Development, 1951-60 compared to Urban Development, 1951

2. Maximum Urban Shadow, 1960 compared to Urban Development, 1960
The "maximum" here is defined by the four indicators of indirect effects on land, i.e. undeveloped subdivisions, non-farm ownerships, farmland for sale, non-farm assessment of agricultural land.

3. Minimum Urban Shadow, 1960 compared to Urban Development, 1960
The "minimum" here excludes areas of higher assessment as an indicator of indirect effects; thus it is based only on those factors reflecting action in the real estate market- land subdivided, sold or on sale for urban purposes.

4. Acres for Urban Development, 1951 per thousand population.

5. Acres for Urban Development, 1951-60, per thousand population.

6. Acres for Urban Development, 1960, per thousand population.

7. Acres Under Maximum Urban Shadow, 1960, per thousand population.

8. Quality of Land Used for Urban Development, 1951-60.

9. Quality of Land Under Maximum Urban Shadow, 1960.
Land affected is identified in terms established by the Ontario Soil Survey: No. 1 arable land - Good; No. 2 arable land - Fair to Good; No. 3 arable land - Fair; No. 4 arable land - Poor; No. 5 arable land - Submarginal.

Comparisons are made between the results for each center to observe differences that may relate to differences in the size of the center.

Sources

Data on the uses of land for urban development was obtained primarily from aerial photographs and land use maps prepared by local planning offices. Wherever possible, local planning officials were relied upon for the interpretation of these materials. No special difficulties were encountered in this phase of the study. "Urban development" by definition extends, in all instances, beyond legal urban limits. Where there are dormitory, industrial or transportation centers close by that are part of the general urban complex, they have been included in the area of "urban development" and are reflected in population figures.

Data on land under "urban shadow" was obtained from a variety of sources. The regional Studies Section of the Community Planning Branch, Department of Municipal Affairs, has made available maps on registered subdivisions. The research assistant was able to determine, with the assistance of planning officers in Lindsay, Stratford and London, which subdivisions were developed and which were lying idle. For the Kingston area, the office of the Kingston Area Planning Board was able to provide the required information on registered and undeveloped subdivisions. Non-farm ownerships of agricultural land were obtained from municipal assessment records. Land in this category will include both land held idle in anticipation of urban development, and tenant farms. Information on farmland assessed at higher than normal rural levels was obtained directly from local assessors. In each case they were able to establish the line of the "assessment-shed" - the area in which an assessment differential has been established on the basis of expected future uses of the land. "Farmland for sale for urban purposes" was identified primarily from information supplied by local realtors. The information for each of these four indications of indirect effects required some interpretation; where some doubt existed, it was decided to err on the side of caution and to choose the smallest acreage figure.

Comparability with Crerar Study

The results of this study are not directly comparable with the

Crerar study on The Loss of Farmland in the Growth of The Metropolitan Regions of Canada. That study determines the loss of farmland per 1000 population increase in the 5-year period between 1951 and 1956. The figures are based on the recorded acreages of farmland in the census districts around the selected centers in 1951 and 1956. The loss of farmland was loss due to all causes - both direct development and indirect sterilization; it was not possible from census data to distinguish the different elements in the loss.

This study also expresses urban impact on land per 1000 population increase. Crerar's term "farmland loss" is not appropriate for this study because one of the main objectives is to determine the extent of "urban shadow" which includes not only farmland lost but farmland which is in some way under pressure from the urban land market. The results of this study are different in the sense that direct loss only is recorded, and for a ten- rather than a five-year period; an estimate of the amount and location of "urban shadow" is made in 1960; and the quality of land affected is determined. The area of "urban shadow" in 1960 per 1000 population cannot, of course, be attributed to the past ten years alone. Thus there are no figures of total farmland loss that are directly comparable with the Crerar study. The two studies can, however, be profitably related in the general sense that they are attempts to ascertain, not only the direct use of farmland but the subtle, and, as it happens, quantitatively more significant indirect impact of urban growth on agricultural land.

Lindsay

Special Characteristics of the Area

Lindsay functions as a service center to a large rural area. For this reason, it has more services than is usual for its population of around 10,000. It has a hospital, public library, district collegiate institute, and armories. It has two weekly newspapers, and one daily. There is a relatively large retail section including four banks and two department stores. It has good communication with its surrounding land but is relatively isolated from industrial centers. One researcher suggests that its isolation is responsible both for preventing large scale industrial expansion and increasing its use as a service center.[4]

<u>Land Directly Used, 1951 and 1960</u>
The use of land for urban development in Lindsay is indicated by the following facts:

In 1951, the total urban development of Lindsay used	2,015 acres
From 1951 to 1960, additional land used for urban development was	205 acres
In 1960, the total urban development of Lindsay used	2,220 acres

Thus the ratio $\dfrac{\text{Urban Development 1951-60}}{\text{Urban Development, 1951}} = \dfrac{\text{205 acres}}{\text{2,015 acres}}$ or about 1/10

The use of land for urban development in terms of population was as follows:

In 1951, when total population was 10,554, urban development used 190.9 acres per 1000 population.
Between 1951 and 1960, urban development used 102.5 acres per 1000 population increase.
In 1960, when total population was 12,553, urban development used 175 acres per 1000 population.

The agricultural quality of the land used for urban development in the ten-year period 1951 to 1960 was as follows:

Good arable land	155 acres or	75.6%
Fair to Good arable land	2 acres or	1.0%
Fair arable land	20 acres or	9.7%
Poor and Submarginal land	28 acres or	13.7%
	205 acres or	100 %

<u>Land Indirectly Affected, 1960</u>
The area of land under "minimum urban shadow" that is, land pressured out of production by market forces, was made up of the following components:

Land subdivided for urban purposes but undeveloped	345 acres
Farmland owned by other than a farmer or rural user	none
Farmland listed for sale for urban purposes	1,295 acres
	1,640 acres

Thus the ratio of $\frac{\text{Minimum Urban Shadow, 1960}}{\text{Urban Development, 1960}} = \frac{\text{1,640 acres}}{\text{2,220 acres}} = \frac{.7}{1}$

The area of land under "maximum urban shadow" includes, in addition to the above elements, farmlands assessed at levels higher than normal rural levels - in net terms, that is land so assessed that does not overlap any of the other three elements of "urban shadow".

Thus, the figure for 1960 is:

Minimum urban shadow..............................	1,640 acres
High assessment of farmland	
(a) gross (with overlap) 2,030 acres	
(b) net	1,150 acres
	2,790 acres

Thus the ratio of $\frac{\text{Maximum Urban Shadow, 1960}}{\text{Urban Development, 1960}} = \frac{\text{2,790 acres}}{\text{2,220 acres}} = \frac{1.25}{1}$

The agricultural quality of the land under "maximum urban shadow" on December 31, 1960, was as follows:

Good arable land	1,190 acres or	42.6%
Fair to Good arable land ...	5 acres or	.2%
Fair arable land	610 acres or	21.8%
Poor and Submarginal land...	985 acres or	35.4%
Total	2,790 acres or	100%

The location of the lands affected by "urban development" and "urban shadow" may be observed from the accompanying maps.

Observations

1. In 1960, there was 25 per cent more land under indirect urban pressure than there was actually used for urban development.

2. More than forty per cent (41.2%) of the area indirectly affected was land assessed at higher than normal rural levels.

3. Urban development in the ten years from January 1, 1951, to December 31, 1960, was more compact and used less land to accommodate the growth in population than was used up to 1951; the new population used about 88 acres less per thousand than the people of Lindsay used up to 1951.

4. In an area of generally "Fair" to "Good" arable land, about 86 per cent of the area directly affected in the last ten years, and 64 per cent of the area indirectly affected in 1960, consisted of farmland in the first three ratings.

5. Most of the new urban development from 1951 to 1960 and the land under "urban shadow" assumes a compact form, with a radius of about one mile from the 1951 built-up limits.

Stratford

Special Characteristics of the Area

Until a few years ago, the CNR shops were the most significant employer in the Stratford area. In the last several years, the CNR has moved its repair shops out of Stratford, with the result that workers have been displaced. One would expect that this would prompt the city to try to attract new industry. To a degree this has been done, but the effect on surrounding land has not been great. The CNR has removed its facilities slowly, so that the effect has not been distressing. Other existing industries in the city - textile and furniture factories, for instance, seem to have taken up the slack. The impression remains that Stratford is a prosperous small community, set in the midst of good farmland. The Stratford Festival has undoubtedly increased the prosperity of the community but this does not seem to be reflected in large land speculation - not as yet, at any rate.

Land Directly Used, 1951 and 1960

The use of land for urban development in Stratford is indicated by

the following facts:

In 1951, the total urban development of Stratford used	2,025 acres
From 1951 to 1960, additional land used for urban development was	620 acres
In 1960, the total urban development of Stratford used	2,645 acres

Thus the ratio $\frac{\text{Urban Development 1951-60}}{\text{Urban Development, 1951}} = \frac{\text{620 acres}}{\text{2,025 acres}}$ or about 1/3.3

The use of land for urban development in terms of population was as follows:

In 1951, when total population was 19,000 urban development used 106 acres per 1000 population.
Between 1951 and 1960, urban development used 206 acres per 1000 population increase.
In 1960, when total population was 22,000, urban development used 120 acres per 1000 population.

The agricultural quality of the land used for urban development in the ten-year period 1951 to 1960 was as follows:

Good arable land	40 acres	or	6.4%
Fair to Good arable land	475 acres	or	76.7%
Fair arable land	none		
Poor and Submarginal land	105 acres	or	16.9%
	620 acres		100%

Land Indirectly Affected, 1960

The area of land under "minimum urban shadow", that is, land pressured out of production by market forces, was made up of the following components:

Land subdivided for urban purposes but undeveloped	120 acres
Farmland owned by other than a farmer or rural user	1,100 acres
Farmland listed for sale for urban purposes	400 acres
	1,620 acres

Thus the ratio of $\frac{\text{Minimum Urban Shadow, 1960}}{\text{Urban Development, 1960}} = \frac{\text{1,620 acres}}{\text{2,645 acres}} = \frac{.64}{1}$

The area of land under "maximum urban shadow" includes, in addition to the above elements, farmlands assessed at levels higher than normal rural levels - in net terms, that is, land so assessed that does not overlap any of the other three elements of "urban shadow". Thus the figure for 1960 is:

Minimum urban shadow	1,620 acres
High assessment of farmland	
(a) gross (with overlap) 3,400 acres	
(b) net..	2,580 acres
	4,200 acres

Thus the ratio of $\frac{\text{Maximum Urban Shadow, 1960}}{\text{Urban Development, 1960}} = \frac{\text{4,200 acres}}{\text{2,645 acres}} = \frac{1.6}{1}$

The agricultural quality of the land under "maximum urban shadow" on December 31, 1960, was as follows:

Good arable land	675	acres or	16.1%
Fair to Good arable land...............	3,210	acres or	76.4%
Fair arable land		None or	-
Submarginal land	315	acres or	7.5%
	4,200	acres	100%

The location and quality of the lands affected by "urban development" and "urban shadow" may be observed from the accompanying maps.

Observations

1. In 1960, there was almost 65 per cent more land under indirect urban pressure than there was actually used for urban development.

2. More than sixty per cent (61.4%) of the area indirectly affected in 1960 was land assessed at higher than normal rural levels.

3. Urban development in the ten years from January 1, 1951 to December 31, 1960 was less compact and used substantially more land to accommodate the growth in population than was used up to 1951; the new population used about 100 acres more per thousand than the people of Stratford used up to 1951.

4. In an area of predominantly "Fair" to "Good" arable land, about 83 per cent of the area directly affected in the last ten years and 92.5% of the area indirectly affected in 1960 consisted of farmland in the first two ratings.

5. The new urban development from 1951 to 1960 had a tendency to scatter within a radius of about three miles from 1951 built-up limits, and "urban shadow" has extended along three of the five radiating highways up to a distance of about four to seven miles from 1951 built-up limits.

Kingston

Special Characteristics of the Area

The chief characteristic of Kingston in relation to this study is that it is surrounded by poor agricultural land. There is no No.1 arable land (Good) in the area. There is a substantial amount of No. 5 arable land (Submarginal).

This means that most farmers show little reluctance to sell their land. There is a high proportion of land for sale. The City of Kingston offers wide employment opportunities, and marginal farmers often give up the struggle to work the land. Instead they

work in Kingston but continue to live in the farmhouse, where expenses are relatively low. A certain number of the farmers identify themselves as "contractors". The switch in occupation seems to have been stimulated by the construction of Highway 401 when men with trucks were employed and thereby designated "contractors". The large and diversified industry in Kingston (in 1958 there were 75 manufacturing establishments producing goods valued at 54.9 million dollars) may be a factor in keeping land values up. They do seem to be fairly high in respect to the poor land in the area. Many farmers are waiting for a subdivider or a big industrial concern to take an interest in their property. This speculative interest appears to be reflected as well in the comparatively high proportion of farmland assessed at higher than normal rural levels.[5]

<u>Land Directly Used, 1951 and 1960</u>

The use of land for urban development in Kingston is indicated by the following facts:

In 1951, the total urban development of Kingston used	4,550 acres
From 1951 to 1960, additional land used for urban development was	1,900 acres
In 1960, the total urban development of Kingston used	6,450 acres

Thus the ratio $\frac{\text{Urban Development, 1951-60}}{\text{Urban Development, 1951}} = \frac{\text{1,900 acres}}{\text{4,550 acres}} = 1/2.4$

The use of land for urban development in terms of population was as follows:

In 1951, when total population was 49,424, urban development used about 92 acres per 1000 population.
Between 1951 and 1960, urban development used about 164 acres per 1000 population increase.
In 1960, when total population was 61,000, urban development used about 106 acres per 1000 population.

The agricultural quality of the land used for urban development in the ten-year period, 1951 to 1960, was as follows:

Good arable land	none	
Fair to Good arable land	1,120 acres or	24.6%
Fair arable land	310 acres or	6.8%
Poor and Submarginal land....	3,120 acres or	68.6%
	4,550 acres	100%

Land Indirectly Affected, 1960

The area of land under "minimum urban shadow" that is, land pressured out of production by market forces, was made up of the following components:

Land subdivided for urban purposes but undeveloped	1,107 acres
Farmland owned by other than a farmer or other rural user	8,165 acres
Farmland listed for sale for urban purposes	3,000 acres
	12,272 acres

Thus the ratio $\dfrac{\text{Minimum Urban Shadow, 1960}}{\text{Urban Development, 1960}} = \dfrac{\text{12,272 acres}}{\text{6,450 acres}} = \dfrac{1.9}{1}$

The area of land under "maximum urban shadow" includes, in addition to the above elements, farmlands assessed at levels higher than normal rural levels - in net terms, that is, land so assessed that does not overlap any of the other three elements of "urban shadow".

Thus, the figure for 1960 is:

Minimum urban shadow .... 12,272 acres

Non-farm assessment of farmland
(a) gross (with overlap) 23,140 acres
(b) net .... 20,840 acres

33,112 acres

Thus the ratio of $\dfrac{\text{Maximum Urban Shadow, 1960}}{\text{Urban Development, 1960}} = \dfrac{\text{33,112 acres}}{\text{6,450 acres}} = \dfrac{5.1}{1}$

The agricultural quality of the land under "maximum urban shadow" on December 31, 1960, was as follows:

Good arable land	none	
Fair to Good arable land	5,300 acres or	16.0%
Fair arable land	7,550 acres or	22.8%
Poor and Submarginal land	20,262 acres or	61.2%
	33,112 acres or	100%

The location and quality of lands affected by "urban development" and "urban shadow" may be observed from the accompanying maps.

Observations

1. In 1960, there was five times more land under indirect urban pressure than there was land actually used for urban development.

2. About sixty-three per cent (62.9%) of the area indirectly affected in 1960 was farmland assessed at higher than normal rural levels.

3. Urban development in the ten years from January 1, 1951 to December 31, 1960 was less compact and used substantially more land to accommodate the growth in population than was used up to 1951; the new population used about 72 acres more per thousand than the people of Kingston used up to 1951.

4. In an area of predominantly "Poor" and "Fair" arable land, about 31 per cent of the area directly affected and 39 per cent of the area indirectly affected in 1960 consisted of farmland in the second and third soil ratings, i.e. "Fair to Good" and "Fair". Most of the land affected was "Poor" and "Submarginal".

5. The new urban development from 1951 to 1960 was dispersed along the six highways that focus on the city for a distance up to twelve miles from 1951 built-up limits; the "urban shadow" followed the same pattern over a more extensive area.

London

Special Characteristics of the Area

London is the metropolis of Western Ontario. It is a center for manufacturing, distributing and finance. The community is backed and surrounded by a prosperous agriculture region, to which it sells, and for which it manufactures. Meanwhile, it reaches out to the markets of the world. Head offices for two life insurance companies and two trust companies are located in London. It has more than 300 highly diversified industries.

Land Directly Used, 1951 and 1960

The use of land for urban development in London is indicated by the following facts:

In 1951, the total urban development of London used	9,975 acres
From 1951 to 1960, additional land used for urban development was	7,045 acres
In 1960, the total urban development of London used	17,020 acres

Thus the ratio $\frac{\text{Urban Development, 1951-60}}{\text{Urban Development, 1951}} = \frac{\text{7,045 acres}}{\text{9,975 acres}} = \frac{1}{1.4}$

The use of land for urban development in terms of population was as follows:

In 1951, when total population was 98,000, urban development used about 102 acres per 1000 population.
Between 1951 and 1960, urban development used about 72 acres per 1000 population increase.
In 1960, when total population was 175,000, urban development used about 97 acres per 1000 population.

The agricultural quality of the land used for urban development in the ten-year period, 1951 to 1960, was as follows:

Good arable land	2,780 acres or	39.4%
Fair to Good arable land	3,135 acres or	44.4%
Fair arable land	20 acres or	.3%
Poor and Submarginal land	1,110 acres or	15.9%
	7,045 acres or	100%

Land Indirectly Affected, 1960

The area of land under "minimum urban shadow", that is, land pressured out of production by market forces, was made up of the following components:

Land subdivided for urban purposes but undeveloped	4,535 acres
Farmland owned by other than a farmer or rural user	7,435 acres
Farmland listed for sale for urban purposes	5,420 acres
	17,390 acres

Thus the ratio $\frac{\text{Minimum Urban Shadow, 1960}}{\text{Urban Development, 1960}} = \frac{\text{17,390 acres}}{\text{17,020 acres}} = \frac{1}{1}$

The area of land under "maximum urban shadow" includes, in addition to the above elements, farmlands assessed at levels higher than normal rural levels - in net terms, that is, land so assessed that does not overlap any of the other three elements of "urban shadow".

Thus the figure for 1960 is:

Minimum urban shadow	17,390 acres
Non-farm assessment of farmland	
(a) gross (with overlap) 23,565 acres	
(b) net	16,065 acres
	33,455 acres

Thus the ratio of $\frac{\text{Maximum Urban Shadow, 1960}}{\text{Urban Development, 1960}} = \frac{\text{33,455 acres}}{\text{17,020 acres}} = \frac{1.9}{1}$

The agricultural quality of the land under "maximum urban shadow" on December 31, 1960, was as follows:

Good arable land	16,940 acres or	50.6%
Fair to Good arable land	14,040 acres or	41.9%
Fair arable land	180 acres or	.5%
Poor and Submarginal land	2,295 acres or	7.0%
	33,455 acres or	100%

The location and quality of lands affected by "urban development" and "urban shadow" may be observed from the accompanying maps.

Observations

1. In 1960, there was about two times more land under indirect urban pressure than there was land actually used for urban development.

2. Forty-eight per cent of the area indirectly affected in 1960 was farmland assessed at higher than normal rural levels.

3. Urban development in the ten years from January 1, 1951 to December 31, 1960 was more compact and used substantially less land to accommodate the growth in population than was used up to 1951; the new population used about 30 acres less per thousand than the people of London used up to 1951.

4. In an area of predominantely "Good" and "Fair to Good" arable land, about 84 per cent of the area directly affected in the last ten years and about 92 per cent of the area indirectly affected, consisted of farmland in the first two ratings. Almost all of the remainder was "Poor" and "Submarginal".

5. The new urban development from 1951 to 1960 was, in the main, in a compact form within three miles from 1951 built-up limits, although some of the development was dispersed along the radiating highways and in small urban centers as far as twenty miles from city limits. The "urban shadow" tended to assume a ring around the urban development and was not widely

dispersed.

Russwurm Study on the Rural-Urban Fringe

While the field work for this study was under way, a study of London's rural-urban fringe was being carried out at the University of Western Ontario by Mr. L.H. Russwurm for his Master's degree in Geography.[6] This study attempts to determine the amount and location of farmland around the city that is "non-farmer owned". The results, plotted on the accompanying map, published with the kind permission of the author, shows the 200-acre rural lots classified in three categories: lots over 50 per cent farmer owned; lots 50 per cent and over non-farmer owned; lots 75 per cent and over non-farmer owned.

Mr. Russwurm's study in a general way confirms our evidence on the existence of a ring of farmland around London - an "urban shadow" - subject to pressure from the urban land market. Comparison of the Russwurm map with the study may on "urban development and urban shadow" suggests that the estimates of this study are conservative.

Mr. Russwurm draws three conclusions of interest to this study:

1. Mixed land uses are associated with main roads.

2. Physiography and the quality of soils are in themselves insufficient to contain urban expansion, if regional and economic forces are strong enough to promote urban penetration into the countryside.

3. The rural-urban fringe is a transitional area and in an uncontrolled form is susceptible to blight.

Comparisons and Conclusions

1. All centers show a substantial area of "urban shadow" - an area of surrounding farmland which is either sterilized for agricultural purposes or subject to pressure gradually pushing it out of agricultural production. From the point-of-view of the impact of urban growth on agricultural land, the "unseen" influence of the town is more important than the tangible evidence of land used for building. The accompanying table

shows that for all four centers the area indirectly affected is substantially greater than the area directly used.

2. About two-thirds (49,700 acres) of the area indirectly affected (73,557 acres) in the four centers was better farmland, rated from "Fair" to "Good".

3. The figures in the table (column 5) suggest that "urban shadow" relative to urban development increases moderately with the size of the center but not to any extent in proportion to the difference in population. This "rule" is broken by Kingston, which, with about one-third of the population of London, has actually about the same amount of "urban shadow", resulting in the area of land indirectly affected being five times greater than the land used, compared to London where the ratio is 2 to 1. The comparatively poor quality of farmland around Kingston appears to be the reason for the greater penetration of the urban land market. This result is consistent with Crerar's findings for Ottawa and Quebec, areas with comparatively unproductive farmland, where "loss of farmland" was two to five times greater than at the other metropolitan areas.

4. The very significant spread between minimum and maximum shadow in all four centers is a reflection of the tendency of assessment practices to anticipate a rise in the market. High assessment-farmland assessed at higher than normal rural levels, ranges between 40 per cent and 60 per cent of the area defined as "maximum urban shadow".

5. For the four selected centers, rate of population growth appears to have no bearing on the extent of "urban shadow". It does, of course, affect urban development 1951 to 1960 relative to the area of urban development in 1951 (column 4); although, in the four centers the amount of land used per person up to 1951 and in the following ten years is an offsetting factor, so that new development as a fraction of total development does not vary strictly in accordance with the differences in the rate of growth. The difference between Lindsay (1/10) and London (1/1.4) at opposite ends of the pole are, of course, due mainly to the much higher rate of growth in London (78 per cent in a ten-year period as compared to 19 per cent for Lindsay).

6. At December 30, 1960, the use of land for urban development in terms of population (column 7) tended to decrease from the small center to the big center. But this was not the case in the ten-year period of growth 1951 to 1960 (column 6). Only London shows a consistent tendency - to compact urban development and an urban shadow (albeit twice the area of development in 1960) which assumes the character of a ring and is not widely scattered. This raises the question of the question of the influence of orderly planning measures on the direct and indirect impact on agricultural land. The London and Suburban Planning Board was formed shortly after the Ontario Planning Act and is reported to have effectively guided growth in an orderly fashion.[7]

7. The extent to which the area of "urban shadow" can be counted as land wasted depends on the land-use effects of its major components. It has been stated that non-farm ownership results in either idle land or the short-term lease that destroys the incentive for sound farming practices. Farmland assessed above normal rural levels creates a tax pressure to sell out. The anticipation of a sale at urban price levels produces the phenomenon known as "land-mining" - the squeezing of the land and the neglect of practices that maintain productivity. And these factors, together with undeveloped subdivisions, create a high price area which in time may cause urban development to leap-frog to cheaper land farther out, which in turn begins to assume "urban shadow" characteristics, becomes too expensive, is by-passed and so on until the blight of farmland is increased many times. This is a process that has been described authoritatively in a number of recent studies. Its substantiation in the selected urban-centered regions is beyond the scope of this study.[8]

8. This study is an experiment and merely opens the door on the subject. A thoroughly comprehensive study of the impact of towns on agricultural land might include the following:

   - a larger sample of towns selected to represent a cross-section of centers by size, in areas of fair to good farmland;
   - examination of direct and indirect impact on land in the fifteen Census Metropolitan Areas;
   - examination of direct and indirect impact on land in other centers with populations over 30,000;

URBAN DEVELOPMENT AND URBAN SHADOW, LINDSAY, STRATFORD, KINGSTON, LONDON

1. Center	2. Pop. 1951	3. Pop. 1960	4. $\frac{\text{Urb. Dev. 1951-60}}{\text{Urb. Dev. 1951}}$	5. $\frac{\text{Urb. Shadow 1960}}{\text{Urb. Dev. 1960}}$	6. A. per 1,000 pop. Incr. 1951-60	7. Urb. Dev. per 1,000 pop. 1960	8. Urb. Shadow per 1,000 pop. 1960	9. Urb. Dev. & Urb. Shadow per 1,000 pop. 1960
Lindsay	10,554	12,553	1/10	Min. $\frac{.7}{1}$ Max. $\frac{1.25}{1}$	102 acres	175 acres	222 acres (max.)	397 acres
Stratford	19,000	22,000	1/3.3	Min. $\frac{.6}{1}$ Max. $\frac{1.6}{1}$	206 acres	120 acres	190 acres (max.)	310 acres
Kingston	49,424	61,000	1/2.4	Min. $\frac{2}{1}$ Max. $\frac{5}{1}$	164 acres	106 acres	542 acres (max.)	648
London	98,000	175,000	1/1.4	Min. $\frac{1}{1}$ Max. $\frac{2}{1}$	72 acres	97 acres	190 acres (max.)	287

(Note: Population figures include, in each region, the people living in outlying settlements, towns and villages, who work in the major center.)

- examination of the direct and indirect impact on land of urban centers in each of the major economic regions of Canada;
- a study of the direct and indirect impact on land of smaller centers (a) within the orbit of a big city (b) outside the orbit of a big city;
- examination of the effect of rates of population growth on centers approximately equal in size at base date;
- consideration of the direct and indirect impact on land of centers with effective regional planning compared with centers without regional planning.

9. Even the tentative results of this study suggest that Canada as a nation cannot afford to be ignorant of the total impact of urban development on agricultural land and that a comprehensive national study, along the lines suggested, is essential if we are to use our land resources to best advantage.

ACKNOWLEDGMENTS

The research assistant has received expert and willing assistance in the gathering of data. Many people have made information available and have offered useful advice and judgment. We believe that their interest reflects the concern which is felt for the problem. Their help is gratefully acknowledged.

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Mr. Don Middleton, Director, Ontario Federation of Agriculture; Professor N.R. Richards, Chairman, Department of Soil Science, Ontario Agricultural College; Dr. John Gillespie, Pedologist, Soils Department, Ontario Agricultural College; Mr. Donald E. Guard, Planning Director, London and Suburban Planning Board; Mr. Paul Bruer, London and Suburban Planning Board; Mr. Robert Quick, Assessor, County of Middlesex; Mr. Tom Byran, Anne Boulton Real Estate, London, Ontario; Dr. E.G. Pleva, Chairman, Department of Geography, University of Western Ontario; Mr. Lorne H. Russwurm, Graduate student, Department of Geography, University of Western Ontario.

Mr. G.G. Muirhead, Planning Officer, Kingston Area Planning Board; Mr. R. Daverne, Assessor, County of Frontenac; Mr. R. Woodruff, Assessor, Township of Kingston; Mr. Colin J. MacLean, Secretary-Treasurer, Township of Pittsburgh Planning Board; Mr. A.A. MacDougald Assessor, County of Perth; Mr. H.J. Graham, Secretary, Stratford Real Estate Board; Mr. Donald Tofflemire, Secretary-Treasurer, Lindsay and Ops Township Planning Board; Mr. E.F. Hall, Assessor, County of Victoria; Mr. L.G. Found, Found Real Estate, Lindsay.

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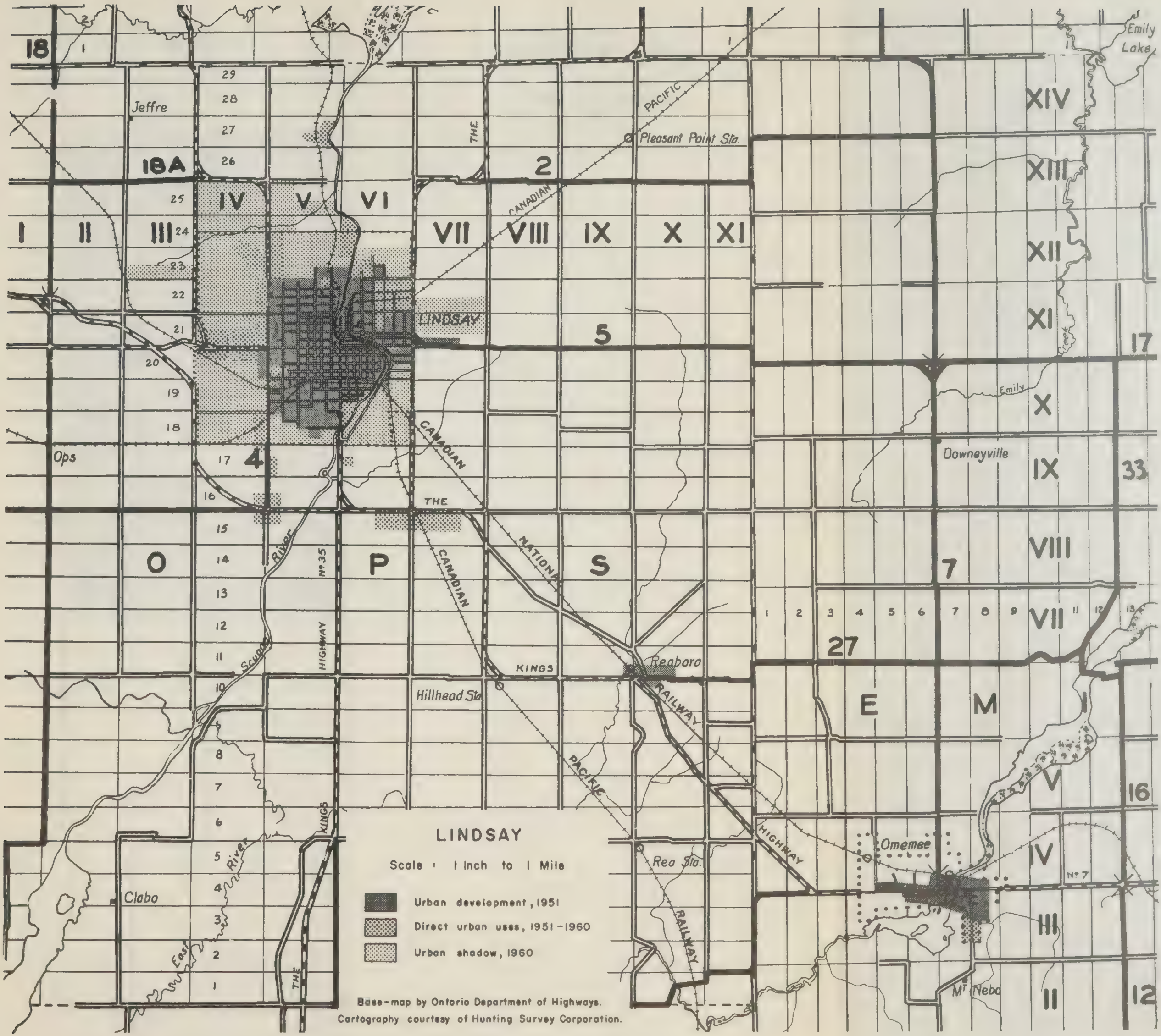
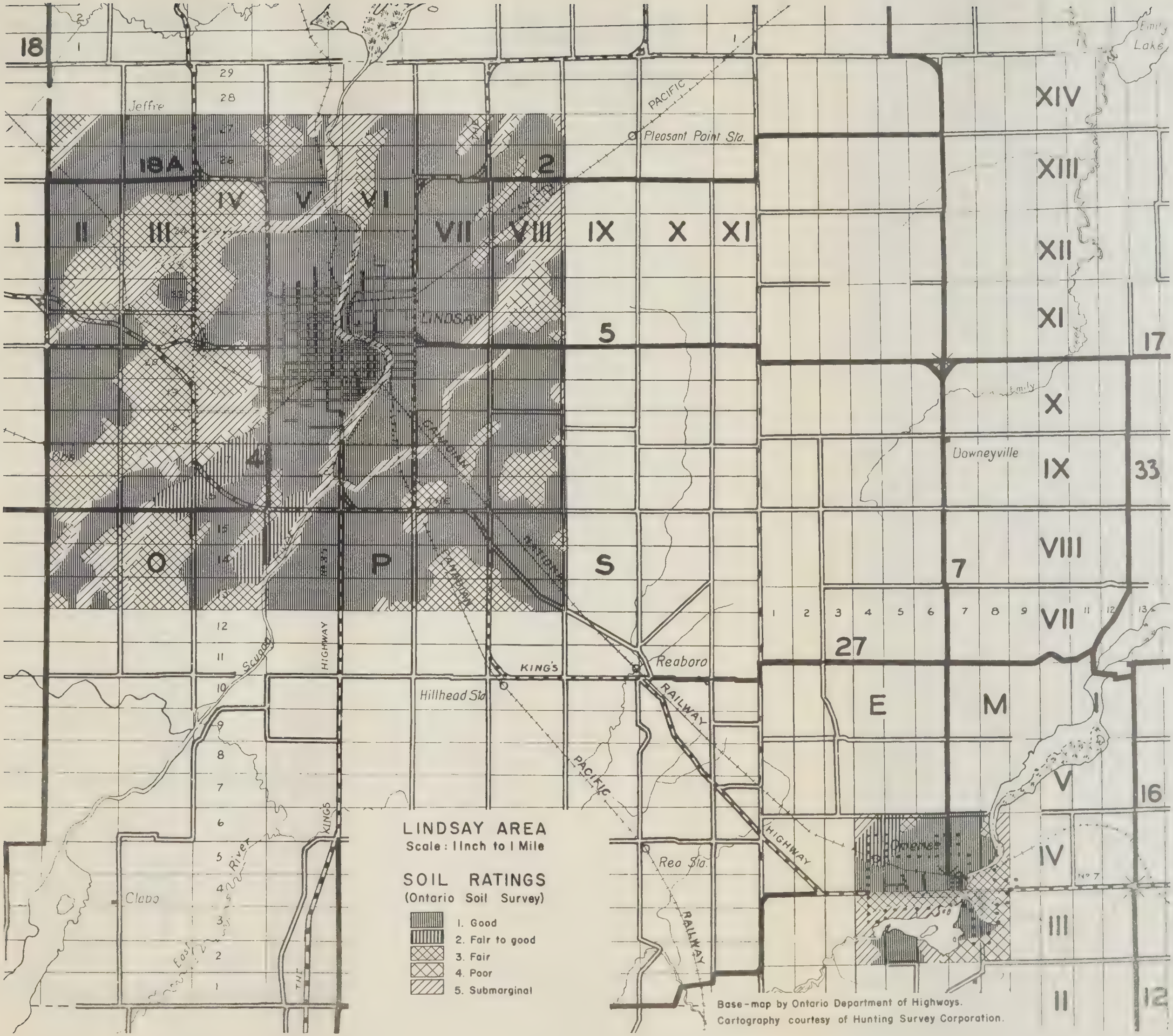
LINDSAY

Urban Development


LINDSAY
Scale : 1 Inch to 1 Mile
Urban development, 1951
Direct urban uses, 1951-1960
Urban shadow, 1960
Base-map by Ontario Department of Highways.
Cartography courtesy of Hunting Survey Corporation.
LINDSAY
Jeffre
Pleasant Point Sta.
Ops
O
P
S
E
M
I
Reaboro
Hillhead Sta
Downeyville
Omemee
Rea Sta.
Clabo
Mt Nebo
Emily Lake
Emily
Scugog River
East River
THE CANADIAN PACIFIC
THE CANADIAN NATIONAL RAILWAY
THE CANADIAN PACIFIC RAILWAY
THE KINGS HIGHWAY
Nº 35 HIGHWAY
THE KINGS
Nº 7
18
18A
2
4
5
7
17
33
27
16
12

LINDSAY AREA

Soil Ratings


LINDSAY AREA
Scale: 1 Inch to 1 Mile
SOIL RATINGS
(Ontario Soil Survey)
1. Good
2. Fair to good
3. Fair
4. Poor
5. Submarginal
Base-map by Ontario Department of Highways.
Cartography courtesy of Hunting Survey Corporation.
Lindsay
Pleasant Point Sta.
Pacific
Reaboro
Hillhead Sta.
Rea Sta.
Downeyville
Omemee
Emily Lake
King's
Highway
Railway
Canadian National
Scugog
East River
O P S
E M I
18
18A
2
5
7
17
33
27
16
12

STRATFORD

Urban Development


STRATFORD
Scale : 1 Inch to 1 Mile
Urban development, 1951
Direct urban uses, 1951-1960
Urban shadow, 1960
Base-map by Ontario Department of Highways
Cartography courtesy of Hunting Survey Corporation
Rostock
Gads Hill Sta.
Gads Hill
Brocksden
Shakespeare
Sebringville Sta.
Tavistock
Harmony
Avonton
St Pauls Sta.
Fairview
Avon River
THE KINGS HIGHWAY
Canadian National Railway
STRATFORD
E L L I C E
N O R T H E A S T H O P E
S O U T H E A S T H O P E
D O W N I E
FE R

STRATFORD AREA

Soil Ratings

STRATFORD AREA
Scale : 1 Inch to 1 Mile
SOIL RATINGS
(Ontario Soil Survey)
1 Good
2 Fair to good
3 Fair
4 Poor
5 Submarginal
Base-map by Ontario Department of Highways
Cartography courtesy of Hunting Survey Corporation
Rostock
Gads Hill Sta.
Brocksden
Harmony
ELLICE
DOWNIE
SOUTH EASTHOPE
NORTH EASTHOPE

KINGSTON AREA

Soil Ratings


KINGSTON AREA
Scale : 1 Inch to 2·5 Miles
SOIL RATINGS
PRELIMINARY
(Ontario Soil Survey)
1. Good
2. Fair to good
3. Fair
4. Poor
5. Submarginal
Base-map by Ontario Department of Highways.
Cartography courtesy of Hunting Survey Corporation.
NORTH CHANNEL
ST LAWRENCE
RIVER
ST LAWRENCE RIVER
LOUGHBOROUGH
GORE

KINGSTON

Urban Development


ERNESTOWN
LOUGHBOROUGH
KINGSTON
PITTSBURGH
WESTERN DIVISION
GORE
NORTH CHANNEL
AMHERST ISLAND
ST LAWRENCE
HOWE ISLAND
RIVER
WOLFE ISLAND
ST LAWRENCE RIVER
KINGSTON
Scale : 1 Inch to 2·5 Miles
Urban development, 1951
Direct urban uses, 1951-1960
Urban shadow, 1960
Base-map by Ontario Department of Highways.
Cartography courtesy of Hunting Survey Corporation.

LONDON

Urban Development

LONDON
Scale 1 Inch to 2·5 Miles
Urban development, 1951
Direct- urban uses, 1951 - 1960
Urban shadow, 1960
City boundary, effective Jan. 1, 1961
Base-map by Ontario Department of Highways.
Cartography courtesy of Hunting Survey Corporation
BIDDULPH
EAST WILLIAMS
WEST NISSOURI
LONDON
LOBO
NORTH DORCHESTER
WESTMINSTER
CARADOC
DELAWARE
GORE
LONDON
ONEIDA INDIAN RESERVE

LONDON AREA

Soil Ratings


LONDON AREA
Scale : 1 Inch to 2·5 Miles
SOIL RATINGS
(Ontario Soil Survey)
1. Good
2. Fair to good
3. Fair
4 Poor
5. Submarginal
BIDDULPH
EAST WILLIAMS
LONDON
LOBO
CARADOC
DELAWARE
WESTMINSTER
NORTH DORCHESTER
Base-map by Ontario Department of Highways.
Cartography courtesy of Hunting Survey Corporation.

LONDON

Percentage of Farmer Owned Land

Data from : Russwurn, Lorne H. "The Rural-Urban Fringe with Comparative Reference to London, Kitchener-Waterloo and Sarnia." M.A. Thesis 1961, Department of Geography University of Western Ontario.

THE LOSS OF FARMLAND IN THE GROWTH OF METROPOLITAN REGIONS OF CANADA

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For some time the problem of the loss of farm land in the burgeoning growth of our cities has been a matter of concern. It has become obvious that as the subdivider and the industrialist moved out into the suburban areas that expansion of the city must necessarily take place with an equivalent contraction of farm land. Views on this process have ranged from alarm to complacency or satisfaction. However, in Canada at least, no over-all examination of the rate of loss of farmland in relation to city growth has been made nor has any comprehensive examination of trends and implications been undertaken.

Careful, detailed examinations of particular problem areas have been undertaken, notably in the Niagara Fruit Belt.[1] These studies would be indispensable to those concerned with development in the region examined, but do not provide material which is generally applicable to the problem of city growth and the conversion of land to nonagricultural uses.

Such a study has been undertaken in the United States. There Bogue posed the question, "Under present conditions, how many acres of land are removed from agricultural production per 1,000 population increase?"[2]

With an answer to this question in conjunction with estimates of city growth, it would be possible to judge reasonably well the extent, incidence, and effect of future city growth on Canadian agriculture. It would also have an incidental value to the planner in giving him some idea of the future form of the city.

Because of the many advantages accruing from an answer to this question the present study was patterned on Bogue's analysis, with some important exceptions, noted later. In particular the same methodology was adopted "Because the conversion of land from agricultural to urban uses has no boundary recognized in official statistics of urban populations, the problem must be attacked in another way. One possibility is to note the amount of decrease of agricultural land with increase in urban population (rather than noting the amount of increase in urban land with increase in urban population). At first this may seem to be an awkward and indirect approach, but actually it views the problem exactly as it usually is stated, 'Is the spread of cities encroaching upon our food supply?' If the answer to this question is affirmative, we should be able to observe a decrease in the number of acres of agricultural land in the vicinity of large metropolitan areas from one census to the next, and to relate the amount of this decrease to the amount of population growth that takes place in the area during the intercensul period. Furthermore, if there is a consistency in the process, we should be able to formulate an average of the number of acres converted per 1,000 population change."[3]

Bogue then proceeded to apply this analysis to the Standard Metropolitan Areas in the United States for the period between 1930 and 1954. For several reasons this methodology is not directly applicable to Canadian conditions.

1. The Census of Canada definition of farmland changed in 1951. In the 1941 census and in previous years a farm was defined as "all holdings one acre or more in size if the 1940 production was valued at $50 or more." In 1951 and 1956 the definition adopted was "a holding on which agricultural operations are carried out and which is: (1) three acres or more in size, or (2) from one to three acres in size, and with the agricultural production in 1950 (1955) valued at $250 or more." Obviously this change in the definition of farmland, though it is certainly more realistic, makes any examination of loss of farmland prior to 1951 impossible. The present study was therefore restricted to the losses of farmland that occurred between 1951 and 1956.

2. The Bogue study was restricted to losses occurring within Standard Metropolitan Areas. The U.S. Bureau of Census has set up a rather strict definition for a metropolitan area, which

must have, for instance, a minimum density of three people per acre. For the Canadian equivalent, Census Metropolitan Areas, the definition is much more flexible and boundaries tend to vary with local conditions. Under these circumstances a direct comparison of loss of farmland within Census Metropolitan Areas only might lead to distorted results.

3. Census Metropolitan Areas do not by any means encompass all the farm lands which are withdrawn from agricultural production by the expanding city. Observations in the Lower Mainland indicate that subdivisions, small holdings, highway commercial uses and industrial developments directly consequent on the expansion of Greater Vancouver occur in a zone extending as far as 40 miles airline distance from the center of Vancouver and some 20 miles beyond the boundary of the Census Metropolitan Area of Greater Vancouver. As evidence of this the result of a survey of the labor force in the Abbotsford-Mission area of the Lower Mainland is shown in Table 1. The material was obtained from the Mission office of the National Employment Service and covers all workers including farm laborers, registered with the Service in 1956.

Table 1

Working in:	LIVING IN:			
	Mission	Maple Ridge	Abbotsford	
Mission Area	67.0%	33.0%	18.7%	
Abbotsford Area	2.6%	4.8%	34.0%	
Between Gt. Van. & Mission, Abbots.	2.4%	10.2%	6.7%	
Greater Vancouver	14.0%	23.8%	30.7%	
Outside Region	14.0%	23.2%	9.9%	
	100.0%	100.0%	100.0%	
	2,480	660	2,860	6,000

Source. The Need for River Crossings in the Central Part of the Fraser Valley, Lower Mainland Regional Planning Board, 1956, p. 23.

Both Mission and Abbotsford are about 40 miles airline from the heart of Vancouver, while the small part of Maple Ridge covered is about 30 miles. The closest boundary of the area surveyed lies about 20 miles beyond the outer limit of Greater Vancouver. Nevertheless anywhere from 14 per cent to 30.7 per cent of the labor force in this area finds work in the Greater Vancouver area, presumably commuting to work daily. A further substantial number find employment completely outside the region, principally on large scale construction projects but also in logging and fishing.

It may be that the labor force in the Lower Mainland is uniquely mobile, but this is unlikely. The pattern of universal car ownership is firmly established across Canada and if workers here are willing to commute in considerable numbers over 40 miles no doubt they would be willing to do so in other sections of Canada.

With these considerations in mind the pattern for this survey was decided on. All metropolitan areas with over 100,000 population in Canada would be examined. Starting with the core city and moving outward, the suburban areas and rural municipalities would be studied successively. If between the Census of Agriculture in 1951 and 1956 the subdivision had lost farmland it was considered to be part of the metropolitan region which had come under the influence of the expanding city.[4] The first rural municipality moving outward from the center of the city which exhibited no decrease in farm acreage, or registered an increase, was considered to close the boundary of the range of influence of metropolitan growth and mark the farthest observable extent of the metropolitan region. A number of bounds for the metropolitan region have been suggested previously such as milk sheds, wholesale distribution areas and newspaper circulation zones but the zone of farmland loss is probably the best direct physical boundary marking the division between metropolis and countryside.

However, "One inherent weakness of the study design should be kept in mind: it is presupposed that all decreases in the amount of agricultural land in the Standard Metropolitan Areas are due to conversion to nonagricultural use. Actually, there is a possibility that farm land is abandoned and returned to woodland, or left as wasteland. In view of the superior position with respect to the market, it would appear that comparatively little abandonment would take place within Standard Metropolitan Areas, but that all land

suitable for agriculture or that could be made suitable for agriculture, would be kept in production until claimed for urban uses."[5]

If this caveat was necessary for a study that stopped at the boundaries of Standard Metropolitan Areas it must be even more carefully considered in a study such as this, carrying the examination outwards until no further evidence of loss of agricultural land could be noted.

Several items indicate that the error introduced by this supposition (that all farmland lost within the metropolitan region is due to urban expansion) is not significant. Some of the evidence is internal to the study such as:

1. The loss of farmland does stop. If the examination had found no boundary to the loss of farmland it would have indicated immediately that there was a general phenomena in no way connected with urban expansion.

2. The boundaries are about where they would be expected. That is, the area affected by loss of farmland is directly proportional to the population of the metropolitan region, largest around the largest centers, smallest around the smaller centers.

3. The loss of farmland proceeds as would be expected. It is greatest closest to the central cities, least on the peripheries. Indeed three fairly regular belts may be discerned.

(a) Inner Belt: Loss of Farm Land, Loss of Improved Land.

(b) Middle Belt: Loss of Farm - Improved Lands remain the same or experience a slight increase at the expense of Unimproved Lands.

(c) Outer Boundary: No loss in farm Lands or an increase - general increase - in Improved Lands.

This kind of pattern would indicate that the superior position that these lands enjoy with respect to the market does exert pressure to retain suitable land in farm use until claimed for urban uses.

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Other evidence in favor of this view is external to the study:

1. The normal commuting radius for a metropolitan area the size of Vancouver is 40 to 50 miles.

2. Studies of the range of price influence of the city indicate that even "As small a city as Eugene, Oreg. (36,000) extends its price influence more than 10 miles from the center (not around a full circle).... the price influence of some of them (cities larger than Eugene) radiates more than 50 miles."[6]

3. Land that is abandoned, returned to woodland or left as wasteland within the metropolitan region is probably due to city expansion or, more properly, the preceding speculative wave in advance of actual city growth. Land which seems superficially to have reverted to wasteland has in fact been subdivided into city lots or small holdings or is abandoned because it is intended to be subdivided within the very near future. That this speculative blight could affect a far larger area than actual physical growth of the city can be seen by the dimensions that it assumes. "The United States Census of Governments, in its Advance Release No.3 for 1957, reported the number of vacant lots on record in the United States at nearly 13 million (not counting parking lots). That is 21 per cent of all city lots, and about 13 times the annual consumption in new constructions."[7] That this phenomena is not confined to the United States is shown by the following analysis of development in a 32.6 square mile urban residential zone on the fringe of the Vancouver metropolitan area.

November 1953 Lots under 1 acre		November 1958 Lots under 1 acre	
Vacant	Built on	Vacant	Built on
3,111	2,863	12,880	7,638

Expansion was very rapid, at the rate of 955 new homes every year, but the creation of new lots proceeded at an even more headlong pace, 1,950 per year or double the rate of the construction of new homes. As a result the outcome of five years of development was the creation of a reservoir of vacant lots equivalent to 13 1/2 years supply at the rate of growth between 1953 and 1958.

That this result corresponds so exactly with the figures quoted by Gaffney is probably no more than coincidence. What is significant is the scale of speculative oversupply and its probable effect on removing land from agricultural production well in advance of actual city growth.

An additional pressure removing land from cultivation in advance of actual city growth is the influence of growth on the municipal tax structure. Subdivision may only be occurring in the part of the municipality closest to the city. However the deficits in municipal revenues that such subdivisions normally produce must be met by tax increases which fall most heavily on farms, thus inducing premature land abandonment directly consequent, though the mechanism is hidden, on city expansion.

For these reasons the method adopted is considered to be adequate and not subject to significant error. However, several conditions seem to be required for the method to give satisfactory results, all of which might be anticipated. The central city must be located in a predominantly agricultural countryside. For example, it was impossible to apply this analysis to Halifax, N.S. since the city is set in an infertile area with very little agricultural development. Distorted results seem to be obtained when the central city borders an infertile area of marginal productivity. These cases will be considered more fully when the results from Ottawa and Quebec are examined.

Disappointingly, the analysis could not be applied to Greater Vancouver. Here two conditions prevail. A good deal of growth has taken place on the steep, infertile slopes of the Coast Range Mountains in North and West Vancouver, which never have and never could be used for agriculture. Secondly, the Lower Mainland never fully developed before it was caught up in modern city expansion. The history of settlement is less than 100 years old, and the last substantial stand of virgin timber was cut in the metropolitan area in 1933. The interval between the going of the forest and the coming of the city has been too short to result in a mature agricultural pattern. Most of the area on which Vancouver expanded was bush; in only one municipality has expansion spilled over onto farmland. In fact, Vancouver has had the most efficient pattern of expansion in Canada in terms of preserving good farmland, though it must be admitted that this course has been due to luck rather than good management. Much the same comments would

apply to Greater Victoria.

In Alberta it was impossible to examine the situation around Calgary and Edmonton. Between 1951 and 1956 there was a wholesale revision of municipal and census district boundaries which makes any meaningful comparision futile.

With these exceptions all the metropolitan areas in Canada with more than 100,000 population were examined. The results of this study are shown in Table 2 on page 189.

The study results are ranged in the rank order of farmland loss. The losses experienced in Ottawa and Quebec seem to be high. Both of these cities border on the Laurentian Shield, a bleak, stony and inhospitable farming area. It would seem that these marginal agricultural areas introduce an error either by giving way too easily to urban penetration or by the actual abandonment of farms. It may be, however, that large withdrawals occurred for recreational purposes. In any event the resulting rate of loss does seem too high.

The remaining metropolitan areas are set in areas of fair to good agricultural capabilities and should present an undistorted picture of the average rate of loss of farmland accompanying population growth. The rate of loss for Windsor seems low. Two explanations can be offered for this.

1. The main difficulty seems to occur in the Township of Sandwich West, bordering immediately on the City of Windsor. In this census division between 1951 and 1956 the population increased by 8,806 while the area of farmland actually increased by 253 acres. If the population and farmland increase for Sandwich West is left out of the calculations for the Windsor metropolitan region the resulting loss of farmland moves up to 321 acres per 1,000 population increase.

2. If, as is suspected, there is a large speculative component to the loss of farmland, the figures for Windsor seem much more reasonable. Though the metropolitan region experienced fairly substantial growth from 1951 to 1956 (13.6%), the expectations of the region were dealt a severe blow with the decision in 1953 to move a major part of the Ford motor works to Oakville. Reputedly this action had a depressing effect on land prices and expectations and probably halted much speculative withdrawal of farmland from production.

Table 2

Metropolitan Region	Population			Farmland in Acres			Loss of Farmland (acres) per 1,000 population increase
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	1951	1956	Population Increase	1951	1956	Loss of Farmland	(7)/(4) X 1,000
Ottawa	317,696	373,281	55,585	665,916	610,260	55,656	1,001
Quebec	316,280	357,530	41,250	347,116	305,995	41,121	1,000
London	137,343	164,014	26,671	288,890	276,659	12,231	458
Winnipeg	365,008	419,142	54,134	529,818	509,077	20,741	383
Toronto-Hamilton	1,733,497	2,142,649	409,152	1,702,480	1,546,221	156,259	382
Montreal	1,589,253	1,874,239	284,986	921,676	815,150	106,526	374
Windsor	176,230	200,173	23,943	111,420	106,815	4,605	192

The four remaining metropolitan regions can be considered strictly in order. London seems to be somewhat on the high side, but it is one of the smallest of the metropolitan regions and special local conditions might be expected to appear. The correspondence of the remaining three seems remarkable, particularly since they are the largest in population and area.

Winnipeg is set on fertile lacustrine soils at the junction of the Red and Assiniboine Rivers. Expansion can only take place onto good agricultural land. Montreal is centered at the widest stretch of the St. Lawrence lowlands where again urban expansion must occupy good farmland. Both are quite isolated in that no other major cities lie within their metropolitan region, with the minor exception of St. Jean in the Montreal metropolitan region.

Toronto-Hamilton must be considered one vast metropolitan region. Loss of farmland is continuous in the townships between Toronto and Hamilton and no meaningful boundary can be drawn between the two centers. Indeed the loss of farmland forms a continuous belt between these centers and number of subsidiary or satellite centers, such as Guelph, Galt and Kitchener-Waterloo. "Mississaga" already exists though its shape is not quite that conceived by Putnam.[8]

The outward movement of Toronto's growth seems to have been principally north and west and neither Whitby nor Oshawa can be included in the Toronto metropolitan region as yet. Similarly Hamilton has not as yet linked up with St. Catharines or Brantford.

When the experience in London, Winnipeg, Toronto-Hamilton and Montreal is consolidated we find a total population increase of 774,943 resulting in a loss of 295,757 acres of farmland or an average loss of 382 acres of farmland for each 1,000 increase in population.

How much of this loss of farmland can be considered a legitimate claim by the city for living room and how much can be counted waste? This is a difficult question. To accommodate something over half a million additional people in Greater Vancouver by 1976 would require 108 acres per 1,000 population increase at what are considered to be very generous planning standards.[9]

If cities only need 108 acres to accommodate an additional

1,000 people but are actually using 382 acres, they might be considered to be wasting 2.54 acres for each one that they consume. Of course the implication of waste assumes that we do in fact want to build a city. If our ideal is Los Angeles and our object urban sprawl - and that, it seems, is what we are building, then there is no "waste" associated with the development of the metropolitan regions between 1951 and 1956.[10] However enough has been said elsewhere of the economic, physical and social problems associated with urban sprawl to hope that the development of our metropolitan regions in this fashion would in fact, be judged waste.

What are the implications for agriculture of the loss of farmland on this scale? The Gordon Commission forecasts that urban areas of more than 100,000 population may hold 56 per cent of Canada's population in 1980. This would mean an increase of 8,800,000 people in and about such centers and, at the average rate of loss between 1951 and 1956, the disappearance of 3,361,000 acres of farmland. Though this loss would be equal to the whole of the farmland in Prince Edward Island and Nova Scotia, it still represents less than 2 per cent of the area of farmland in Canada as a whole in 1956. It is less than the loss of occupied farmland in eastern Canada between 1951 and 1980 forecast by Drummond and MacKenzie in their report to the Gordon Commission, though most of the loss they were considering consisted of marginal production.[11] What may be significant is the key location where much of this loss will take place; the Niagara Fruit Belt or the Lower Mainland of British Columbia, for example.

The City of Montreal in their brief to the Gordon Commission forecast a population of 3,521,000 within a 30 mile radius by 1981. This would be an increase of 1,680,000 people and could be accompanied by the removal of 642,000 acres of farmland from production, equivalent to 79 per cent of the farmland included within the metropolitan region of 1956. (See map). But Drummond and MacKenzie already foresee "... substantial estimated increases in per capita consumption of certain key products for which Quebec is now in a deficit position (beef, pork, poultry and eggs, cheese and tomatoes), it is to be expected that Quebec will, in general, remain a deficit agricultural area during the next 25 years. This generalization would apply with special force to a dominant metropolitan market like Montreal".[12] This generalization did not depend on the loss of farmland on the scale visualized here. The farmland to be lost in the expansion of Montreal is probably the most

productive in Quebec. Average cash income in the St. Lawrence Lowlands is 36 per cent higher than in the Appalachian region and more than double that in the Laurentian region.[13]

Though the implications of the loss of farmland are worthy of study on the part of agriculturalists, the major lessons are for city and regional planners.

1. People by their settlement patterns and actions are today building vast metropolitan regions, not consciously, but by the decision to live 40 miles from where they work, and find their recreation 50 miles from where they live.

2. These decisions are affected by the subdivision of farmland here, the construction of a road there, the tapping of water supplies, the cutting of timber in river valleys and the pollution of streams.

3. These decisions are often permanent. The grain of the landscape is being set in the subdivision pattern and the road layout; the character of the region is being molded for good or ill by the other decisions.

4. These decisions are being taken beyond as well as within the boundaries of most metropolitan or district planning areas. The Lower Mainland Region, the Alberta District Planning Commissions and probably the Winnipeg Metropolitan planning area are the only bodies in Canada where the planning function covers the whole area of the metropolitan region.

5. In other sections of Canada the metropolis will in time inherit the decisions in city building now being made within the metropolitan region. Some of the decisions they inherit may be good, if they are it is entirely a matter of luck, since they were not taken with their ultimate purpose in mind.

We are building blindly. At best planning decisions are being made in divided jurisdictions, at worst they are being made for only part of the effective physical area, or not at all. The metropolitan region as defined here is the only technically defensible metropolitan planning unit. Any lesser planning area, however reasonable on historic, administrative or political grounds, is simply

incapable of handling the problems that are arising. Even if the loss of agricultural land on the scale envisaged in this report were considered to be a problem, we have at present no way in which we could prevent it. Until such time as planning decisions can be made for the whole of the area of our metropolitan regions this question, among many others, can not be dealt with.

Notes and References

1 Changing Land-Use Patterns in the Niagara Fruit Belt. Ralph R. Krueger, Transactions of the Royal Canadian Institute, No. 67, October, 1959.

2 Donald J. Bogue, Metropolitan Growth and the Conversion of Land to Non-Agricultural Uses, No. 11, Scripps Foundation Studies in Population Distribution, Oxford, Ohio, 1956, p . 6.

3 Ibid p. 6-7

4 Hereafter the metropolitan region will refer to the whole area about the core city which has experienced a loss of farmland.

5 Bogue, p. 7. In the opposite direction the introduction of new farmlands by reclamation, irrigation etc. could understate the losses consequent on city expansion.

6 Urban Expansion, M. Mason Gaffney, Land, The Yearbook of Agriculture, 1958, U.S. Dept. of Agriculture, Washington D.C. p. 512.

7 Ibid p. 521

8 Mississaga, D.F. Putnam, Community Planning Review, Vol. 4, 1954, p. 93-96.

9 Standards: Industrial: Density 10 employees per gross acre.
Commercial: 2.65 acres per 1,000.
Parks and Schools: 12.35 acres per 1,000.
Residential : 13 per acre gross.

These standards were adapted from "Population and Land Use Forecasts", Technical Report #1, A Study on Highway Planning, Part II, Research and Development Section, City Planning Dept., Vancouver, B.C. for the Technical Committee for Metropolitan Highway Planning, 1958-1959. The residential density adopted was my own, allowing each family a free standing house on a typical city lot. The resulting over-all

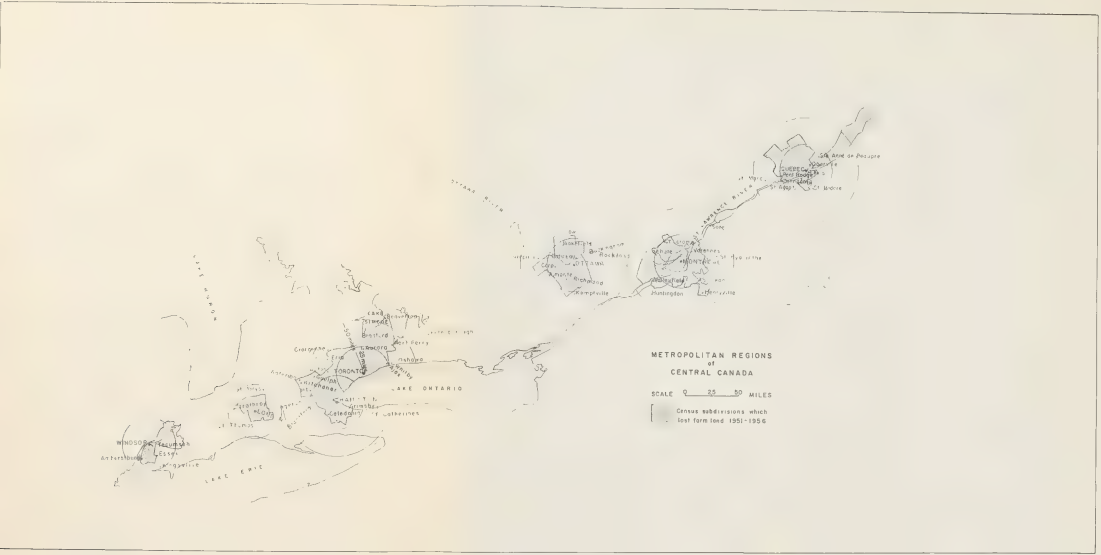
gross density would be 9.2 people per acre.

10 At 382 acres per 1,000 population increase the farmland removed from production would be developed at an over-all gross density of 2.6 people per acre. "Sprawl is a stage of transition between true agricultural development, which has a density less than 0.3 people per acre, and suburban residential development, with a density greater than 3.5 people per acre." Economic Aspects of Urban Sprawl, Lower Mainland Regional Planning Board, New Westminister, May, 1956, p.8.

11 Progress and Prospects of Canadian Agriculture, W.M. Drummond and W. MacKenzie, Report to the Gordon Commission, Jan. 1957, p. 97.

12 Ibid p. 190

13 Ibid p. 170


METROPOLITAN REGIONS
of
CENTRAL CANADA
SCALE 0 25 50 MILES
Census subdivisions which lost farm land 1951-1956
QUEBEC
St. Anne de Beaupre
ST. LAWRENCE RIVER
Sorel
MONTREAL
Varennes
Valleyfield
Huntingdon
Henryville
OTTAWA
Rockland
Richmond
Kemptville
LAKE SIMCOE
Bradford
Aurora
Port Perry
Oshawa
Whitby
Ajax
TORONTO
Kitchener
LAKE ONTARIO
Grimsby
Caledonia
WINDSOR
Tecumseh
Essex
LAKE ERIE
LAKE HURON